

# Development of a Portable Digital Device Based on a Gas Sensor for Self-Detection of Halitosis

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**Abstract.** Halitosis is a highly prevalent oral health problem that impacts quality of life and social interactions. However, it often goes undetected due to individuals' limited ability to recognize their own breath odor. The limitations of available examination methods, which are often subjective and impractical for self-monitoring, highlight the need for a portable and user-friendly device. This study aimed to develop and evaluate the feasibility of a portable gas sensor-based prototype for self-monitoring oral malodor indicators. The study employed a Research and Development (R&D) approach consisting of needs identification, prototype development, expert validation, and user feasibility testing involving 50 respondents. Content validity was assessed using Aiken's V, while user acceptance was evaluated descriptively based on the Technology Acceptance Model (TAM). The results showed an Aiken's V value of 0.916, indicating very high validity in terms of functionality, design, and usability. User feasibility testing demonstrated positive acceptance, with the prototype perceived as useful, practical, and easy to use. These findings indicate that the developed prototype is feasible and acceptable as a self-monitoring tool to support oral health awareness. Further studies are required to evaluate technical performance and clinical validity before wider implementation.

**Keywords:** Halitosis, H<sub>2</sub>S, Gas Sensor, Self-Monitoring, Oral Health Awareness

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## INTRODUCTION

Halitosis is a dental and oral health problem that significantly impacts an individual's quality of life, particularly in psychosocial aspects and interpersonal interactions. From a public health perspective, halitosis is viewed not only as a clinical condition but also as a problem related to health behavior and self-perception. Data from the Indonesian Health Survey shows that oral hygiene issues, including bad breath, remain a common complaint in the community (Ministry of Health of the Republic of Indonesia, 2023). Globally, the prevalence of halitosis is reported to reach 20–50% of the population, indicating that this condition is a significant health issue (Memon et al., 2023).

In the adolescent and early adult age groups, halitosis becomes a more complex issue because this group is in a phase of active social development and has a high level of interpersonal communication. Bad breath can affect self-confidence, increase social anxiety, and hinder interactions with the surrounding environment (Briceag et al., 2023; Alssum et al., 2023; Azodo et al., 2010; Lee et al., 2022). Therefore, adolescents and college students are relevant populations to study in the development of technology-based halitosis detection innovations. Most cases of halitosis are caused by the activity of anaerobic bacteria in the oral cavity, which produce volatile sulfur compounds (VSCs), primarily hydrogen sulfide (H<sub>2</sub>S), methyl mercaptan, and dimethyl

sulfide (Memon et al., 2023; Hampelska et al., 2020). Among these compounds, H<sub>2</sub>S is the primary biomarker most frequently used in halitosis assessment due to its dominant and stable concentration in breath (Kwon et al., 2022; Nakhleh et al., 2018). This suggests that halitosis detection requires an objective, indicator-based approach that can be accurately measured.

However, a major challenge in halitosis detection is the individual's limited ability to recognize their own breath odor (self-smell limitation). Many individuals are unaware of their condition and therefore do not take preventive measures or seek further testing (Ali et al., 2023; Chien et al., 2020; Mosor et al., 2020). Conventional detection methods, such as organoleptic examination, are still subjective and require professional expertise, making them unsuitable for self-monitoring (Aydin, 2022; Xu et al., 2024). Meanwhile, modern detection devices such as the Halimeter® and OralChroma™ have limitations in terms of cost, portability, and the need for trained operators (Guedes et al., 2020). The development of Metal Oxide Semiconductor (MOS)-based gas sensor technology offers opportunities for the development of more practical and objective halitosis detection devices. Gas sensors have the ability to detect chemical compounds at low concentrations and have been widely used in healthcare as non-invasive diagnostic tools (Goel et al., 2023; Divyashree & Singha, 2025; Harun-Or-Rashid et al., 2025; Velusamy et al., 2023). One potential sensor is the MiCS-5524, which has high sensitivity to H<sub>2</sub>S and can be integrated with portable digital systems (SGX Sensortech, 2023).

Furthermore, the development of mobile health (mHealth) technology allows the integration of devices with digital systems that can display measurement results in real-time and support independent health monitoring (Purushothaman et al., 2023; Naddeo et al., 2017). This approach aligns with developments in modern health technology, which emphasizes the active role of individuals in self-monitoring their health.

In the context of public health, the development of technology-based halitosis detection devices holds significant potential to support promotive and preventive efforts. Technology-based early detection has been shown to increase health awareness and encourage behavioral changes toward better hygiene practices (Ilmi et al., 2020; Dallery et al., 2015). This demonstrates that technological innovation not only has clinical value but also contributes to improving people's quality of life. Although research related to halitosis continues to grow, most still focuses on clinical therapeutic aspects and has not examined the development of technology-based detection devices that can be used independently. Furthermore, research on user acceptance of halitosis detection technology is also limited. This indicates a research gap in the development of portable, affordable, and self-usable halitosis detection devices (Carvalho et al., 2025). Based on this description, this study aims to develop a portable digital device based on a gas sensor and assess its feasibility as a self-monitoring tool for halitosis detection. This research is expected to contribute to the development of innovative health technologies and support increased awareness and behavior regarding oral hygiene in the community.

## **METHODS**

This study employed a Research and Development (R&D) approach adapted from the development model proposed by Sugiyono, which is derived from the Borg and Gall framework. This model was selected because it provides a systematic process for developing, validating, and evaluating health-related products. The development process consisted of five stages: needs identification, product design, prototype development, expert validation, and user feasibility testing. The needs identification stage was conducted through a literature review and field analysis. Literature was searched through Google Scholar, PubMed, and ScienceDirect databases using keywords including “halitosis”, “volatile sulfur compounds”, “hydrogen sulfide”, “gas sensor”, and “self-monitoring oral health”. Articles published between 2020 and 2025 were reviewed to identify limitations of existing halitosis detection methods and define the technical specifications of the proposed device.

Field analysis was conducted through structured interviews with the head of a primary health center, a dentist, and a dental therapist at Leuwigoong Primary Health Center, Garut

Regency, Indonesia. The interviews explored current halitosis assessment practices, barriers to objective diagnosis, accessibility of existing detection methods, and the need for a portable self-monitoring device. Findings from this stage indicated that halitosis assessment remains largely subjective, objective diagnostic tools are rarely available in routine practice, and a practical portable device is needed to support independent monitoring and oral health promotion activities.

The prototype consisted of a MiCS-5524 gas sensor integrated with a Wemos D1 Mini ESP8266 microcontroller, an OLED display module, a rechargeable battery system, and a charging module. The MiCS-5524 sensor was selected because of its sensitivity to hydrogen sulfide (H<sub>2</sub>S), one of the principal volatile sulfur compounds associated with intraoral halitosis. The operational workflow of the device involved the detection of H<sub>2</sub>S gas from exhaled breath by the gas sensor. Changes in sensor resistance were processed by the ESP8266 microcontroller and converted into relative H<sub>2</sub>S response values. Prior to measurement, the device underwent a warm-up period to stabilize sensor readings. Breath samples were directed through a dedicated sampling pathway designed to minimize environmental interference. Measurement results were displayed directly on the OLED screen to facilitate user interpretation.

Expert validation was conducted to evaluate the feasibility of the prototype in terms of functionality, design, technical aspects, safety, usability, and suitability for promotive-preventive oral health purposes. Three experts participated in the validation process, consisting of a dental health expert, an information technology expert, and a public health expert. The assessment instrument consisted of 16 items rated using a five-point Likert scale ranging from 1 (very inappropriate) to 5 (very appropriate).

Content validity was analyzed using Aiken’s V coefficient according to the formula:

$$V = \Sigma s / [n(c - 1)]$$

Where V is the content validity coefficient, s is the score assigned by each validator minus the lowest score category, n is the number of validators, and c is the number of rating categories. An Aiken’s V value above 0.80 was interpreted as indicating very high validity. Following expert validation and prototype refinement, user feasibility testing was conducted among 50 respondents aged 15–16 years. Participants were recruited from a junior high school setting and represented adolescent users as the target population for preliminary feasibility assessment. User acceptance was evaluated using a questionnaire based on the Technology Acceptance Model (TAM), which included the constructs of Perceived Usefulness (PU), Perceived Ease of Use (PEOU), Attitude Toward Using (ATU), and Behavioral Intention to Use (BI). Responses were measured using a five-point Likert scale. Data were analyzed descriptively using frequencies, percentages, mean values, and standard deviations.

## RESULTS AND DISCUSSION

### Needs Identification

The needs identification stage was conducted through a literature review and structured interviews with oral health stakeholders, including the head of a primary health center, a dentist, and a dental therapist. The findings are summarized in Table 1.

Table 1. Summary of Needs Identification Findings

Stakeholder	Key Findings	Implications for Device Development
Head of Primary Health Center	Halitosis is rarely reported as a primary complaint. Limited awareness and accessibility to oral health services reduce opportunities for early assessment.	A portable device is needed to facilitate self-monitoring and support promotive-preventive oral health programs.
Dentist	Current halitosis assessment relies on subjective organoleptic examination and	The device should provide an objective and practical

	observation of oral conditions such as plaque, calculus, caries, and retained roots. Objective assessment tools are not readily available in routine practice.	method for preliminary halitosis assessment.
Dental Therapist	Practical and standardized halitosis detection tools are unavailable in community settings. Self-monitoring tools are considered important for oral health promotion activities.	The device should be portable, easy to use, and suitable for community-based oral health programs.

The findings indicate that existing halitosis assessment methods remain largely subjective and inaccessible for routine self-monitoring. Stakeholders consistently identified the need for an objective, portable, and user-friendly device capable of supporting independent monitoring of oral malodor. These findings served as the basis for developing the portable gas sensor-based prototype evaluated in this study.

### Respondent Characteristics

Table 2. Respondent Age Distribution

Variable	N	Minimum	Maximum	Mean	SD
Age	50	15	16	15.38	0.49

Source: SPSS output data

Based on the analysis results in Table 2, the study involved 50 respondents aged 15–16 years, with a mean age of 15.38 years (SD = 0.49). The relatively small standard deviation indicates a homogeneous age distribution among participants. This homogeneity enabled feasibility testing within a population with similar developmental and psychosocial characteristics. However, because the sample was limited to adolescents, the findings may not be generalizable to adults, older individuals, or clinical populations.

Table 3. Gender Distribution

Gender	N	%
Male	19	38%
Female	31	62%

Source: SPSS output data

Based on the analysis results in Table 3, female respondents constituted the majority of the sample (62%), whereas male respondents accounted for 38%. Since the present study did not compare user responses according to gender, no conclusions can be drawn regarding gender-related differences in technology acceptance. Nevertheless, the predominance of female participants should be considered when interpreting the findings because perceptions of oral hygiene and self-monitoring behaviors may vary across demographic groups.

### Expert Validation

Expert validation was conducted by three experts consisting of a dental specialist, an information technology expert, and a public health expert. The assessment covered functionality, design, and usefulness of the developed prototype.

Table 4. Expert Validation Results

Assesment	Aspect Aiken's V	Category
Functionally	0,91	Very High
Design	0,92	Very High
Usefulness	0,92	Very High
Average	0,916	Very High

Source: SPSS output data

Expert validation results demonstrated very high validity across all assessment dimensions. The overall Aiken's V value of 0.916 indicates strong agreement among experts regarding the appropriateness of the prototype in terms of functionality, design, and intended usefulness. These findings suggest that the developed device meets the feasibility requirements for further user evaluation. However, expert validation assessed content validity and product feasibility rather than diagnostic accuracy or clinical performance.

### User Feasibility Test

The user feasibility test results indicate that the device is rated well in terms of ease of use, practicality, and acceptability.

Table 5. Feasibility Test Results Based on User Perception

<b>Construct</b>	<b>Mean</b>	<b>SD</b>	<b>Interpretation</b>
PU (Perceived Usefulness)	4.245	0.491	Very Good
PEOU (Perceived Ease of Use)	3.855	0.569	Good
ATU (Attitude Toward Using)	4.120	0.661	Very Good
BI (Behavioral Intention to Use)	3.890	0.722	Good

Source: SPSS output data

The results indicate positive acceptance across all TAM constructs. Perceived Usefulness (PU) achieved the highest mean score, suggesting that participants considered the device beneficial for supporting awareness and monitoring of oral health conditions. Perceived Ease of Use (PEOU) was also positively rated, indicating that the prototype could be operated with minimal training.

Attitude Toward Using (ATU) reflected favorable perceptions toward the device, while Behavioral Intention to Use (BI) indicated a positive willingness to continue using the technology in the future. Overall, these findings demonstrate that the prototype was perceived as useful, practical, and acceptable by the target users. Nevertheless, user acceptance findings should be interpreted as evidence of feasibility and usability rather than proof of diagnostic accuracy or clinical effectiveness.

The needs identification findings indicated that halitosis screening has not yet become a routine component of oral health services. Current practices remain largely focused on curative management, while aspects related to quality of life and self-monitoring have not been fully integrated into routine care (Elissen et al., 2013; Taylor et al., 2014). Structured interviews with oral health stakeholders revealed limited availability of objective halitosis assessment tools and highlighted the need for a practical, portable device that can be used independently. These findings reflect a gap between existing service practices and the contemporary public health paradigm, which emphasizes promotive and preventive approaches, patient empowerment, and quality-of-life-oriented care (Khounghanian et al., 2023; Izidoro et al., 2022).

Halitosis is not only a biological condition but also a psychosocial concern that may affect self-confidence, interpersonal relationships, and social communication (Memon et al., 2023; Lee et al., 2023; Mento et al., 2021). Nevertheless, currently available assessment methods, particularly organoleptic examination, remain subjective and may be less suitable for routine self-monitoring because they depend on examiner judgment and professional involvement (Aydin, 2022). These limitations highlight the need for more accessible and user-friendly technological approaches. In the present study, a Metal Oxide Semiconductor (MOS)-based gas sensor was integrated into a portable digital prototype designed to support self-monitoring and preliminary halitosis assessment. Previous studies have demonstrated the potential of MOS-based gas sensors for detecting volatile sulfur compounds associated with oral malodor (Goel et al., 2023; Stewart et al., 2024). Therefore, the development of a portable sensor-based device may provide a practical alternative that is more accessible to users outside clinical settings.

The expert validation results demonstrated very high validity across all assessment dimensions, with an overall Aiken's V value of 0.916. This finding indicates strong agreement among experts regarding the functionality, design, usability, and intended application of the developed prototype. The high validation score suggests that the device components, operational workflow, and self-monitoring concept were considered appropriate by experts from dentistry, information technology, and public health disciplines (Chau et al., 2024; Zhang et al., 2024). However, expert validation evaluated content validity and product feasibility rather than technical measurement performance or clinical diagnostic effectiveness.

From a technology acceptance perspective, the study results showed that perceived usefulness was higher than perceived ease of use, indicating that participants recognized the potential benefits of the device while identifying opportunities for further improvement in usability. This finding is consistent with the Technology Acceptance Model (TAM), which proposes that perceived usefulness and perceived ease of use are key determinants of technology adoption. Consequently, future development should focus on improving operational simplicity, interface design, user guidance, and overall user experience.

Furthermore, the positive acceptance scores suggest that the device has potential as a self-monitoring tool capable of providing users with immediate information regarding their oral condition. Real-time feedback has been reported to play an important role in supporting health awareness and encouraging preventive health behaviors (Marcolino et al., 2018; Purushothaman et al., 2023). Positive scores across all TAM constructs indicate that users perceived the device as useful, practical, and acceptable for independent use. These findings support the potential implementation of portable digital technologies in oral health promotion and self-monitoring programs. However, the present findings should be interpreted primarily as evidence of product feasibility and user acceptance rather than evidence of diagnostic accuracy or clinical effectiveness.

## **STUDY LIMITATIONS**

Several limitations should be considered when interpreting the findings of this study. First, the user feasibility assessment was conducted exclusively among adolescents aged 15–16 years from a single educational setting. As a result, the findings may not be directly generalizable to other age groups, including adults, older individuals, or populations with different levels of health literacy, digital literacy, and self-monitoring behavior. Second, the study was designed as a Research and Development (R&D) project focusing on needs identification, prototype development, expert validation, and user feasibility assessment. Therefore, the scope of evaluation was limited to product feasibility and user acceptance. Technical performance characteristics, including measurement accuracy, sensitivity, specificity, repeatability, response time, calibration stability, and agreement with established reference instruments for halitosis assessment, were beyond the scope of the present study and were not evaluated. Third, the study assessed user acceptance through the Technology Acceptance Model (TAM), which reflects perceived usability and acceptance rather than long-term behavioral outcomes. Consequently, the extent to which regular use of the device may influence oral hygiene practices, health awareness, or halitosis management remains unclear. Future studies should involve more diverse populations, incorporate comprehensive technical validation procedures, compare device measurements with established reference standards, and evaluate the long-term impact of device utilization on oral health behavior and self-monitoring practices.

## **CONCLUSION**

The portable digital gas sensor-based prototype demonstrated a very high level of feasibility, as indicated by an overall Aiken's V value of 0.916. User feasibility assessment based on the Technology Acceptance Model (TAM) also showed positive acceptance across all evaluated constructs, including perceived usefulness, perceived ease of use, attitude toward using, and behavioral intention to use. These findings indicate that the developed prototype is feasible and acceptable as a self-monitoring tool intended to support oral health awareness. The study

contributes to the development of portable health technologies that support promotive and preventive approaches in dental and oral healthcare. However, the findings should be interpreted as evidence of product feasibility, usability, and user acceptance rather than evidence of diagnostic accuracy or clinical effectiveness. Future research should focus on improving the user interface, integrating the device with mobile health applications, conducting comprehensive technical validation, and evaluating device performance among more diverse populations. Additional studies are also needed to assess measurement reliability, calibration performance, comparison with reference instruments, and the long-term impact of the technology on oral health awareness and self-monitoring behavior.

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