JMHT: Journal of Medicine and Health Technology
Vol. 03, No. 01, May, 2026, pp. 1-8
ISSN: 3046-6865
DOI: 10.12962/j30466865.v3i1.2629

Breath Smoke Detection: Non-Invasive Assessment of Substances Found in Cigarettes

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Abstract — Breath analysis not only holds great potential for the development of new non-invasive diagnostic methods, but also for the identification and follow up of drug levels in breath. This is of interest for both, forensic and medical science. On the one hand, the detection of drugs of abuse in exhaled breath-similar to the well-known breath alcohol tests-would be highly desirable as an alternative to blood or urine analysis in situations such as police controls for drugged driving. Despite the many benefits and conveniences offered, the use of this useful tool is currently still very rare and requires shipping from abroad. Development is needed to realize it in a more affordable version, so researchers discuss further in this paper.

Keywords — *breath analysis; carbon monoxide; smoke breath analyzer.*

How to cite: Hidayah RN. Breath Smoke Detection: Non-Invasive Assessment of Substances Found in Cigarettes. Journal of Medicine and Health Technology. 2026;3(1):1-8. doi: 10.12962/j30466865.v3i1.2629

Manuscript received 30 Jan. 2025; revised 25 Aug. 2025; accepted 28 Feb. 2026. Date of publication 4 May 2026.

INTRODUCTION

Tobacco is widely recognized as a major contributor to early morbidity and mortality around the world. The well-established serious health impacts of cigarette smoking highlight the need for targeted research on smoking behavior and exposure to smoke. To assess the health risks associated with smoking, it is essential to evaluate the level of smoke a smoker is exposed to through their smoking habits [1]. According to the World Health Organization (WHO), smoking accounts for 12% of deaths in men and 6% in women globally. Indonesia, being one of the largest tobacco markets in the world, is heavily impacted by tobacco-related health issues. The burden of disease in Indonesia is increasing every year. Previous studies have indicated that smoking leads to a range of diseases, such as stroke, cancer, and coronary heart disease [2].

Since 2007 to 2013, the percentage of the population in Indonesia aged 15 years and older who smoked or chewed tobacco showed a gradual increase, as reported by the 2007 National Basic Health Research at 34.2% and the 2010 National Basic Health Research at 34.7%. By the end of 2013 National Basic Health Research, the proportion of daily smokers aged 10 years and older was 33.4%, but this figure dropped to 24.3% in 2018. Despite this decline, tobacco consumption in Indonesia remains relatively high. Moreover, the data indicates a rising trend in tobacco use among children and adolescents. The smoking prevalence in the 10–19 years age group increased from 7.2% in 2013 to 9.1% in 2018, marking an almost 20% increase compared to the previous five years [3].

Smoking traditional (combustible) cigarettes is known to change the composition of human breath, introducing a variety of chemicals. Cigarette smoke contains many volatile organic compounds (VOCs), some of which are not normally found in the human body, making them specific markers of smoking (e.g., acetonitrile). Traditional cigarettes are reported to contain over 7,000 different chemicals, many of which are harmful to the user. Among these are 60 known carcinogens (such as heavy metals and carcinogenic aldehydes), along with around 300 nitrosamines, some of which are recognized as highly dangerous carcinogens. A study identified 266 VOCs in the exhaled breath of smokers, with more than 80 of these compounds, primarily unsaturated hydrocarbons, being directly linked to smoking. While e-cigarette vapor is less complex, it still contains potentially harmful substances, the effects of which are only beginning to be understood [4].

These findings raise the question of whether breath analysis could serve as a complementary or alternative method for identifying drugs, similar to the well-established use of breath alcohol analysis, and for monitoring drug levels in the blood. Compared to blood or tissue analysis, breath tests offer several advantages. Breath sampling is non-invasive and painless, and since breath is continuously available, it allows for ongoing analysis. This is particularly useful in situations where repeated or even continuous monitoring is needed, such as with mechanically ventilated patients. In contrast, processing blood and tissue samples requires complex laboratory analysis, which is time-consuming and may not always be feasible at the point of care. Therefore, alternative non-invasive diagnostic methods that can be used directly at the bedside are of significant medical value. The analysis of VOCs and non-volatile substances in human breath could fulfill these needs, providing a complement to continuous monitoring of therapeutic interventions beyond the limitations of blood tests [5].

Breathomics is the study of the composition of exhaled breath, which has the potential to simplify the diagnosis and classification of various respiratory conditions. Exhaled breath contains thousands of VOCs, which include both exogenous VOCs (from environmental factors, food, beverages, and medications) and endogenous VOCs (such as metabolic byproducts and those from microbiota). Essentially, any biochemical changes in cells, including those caused by diseases, can alter blood composition, which may then be reflected in breath through the exchange of VOCs in the lungs. Compared to blood, stool, and urine, breath is a simpler medium, making its collection and data analysis more straightforward [6].

DISCUSSION

The Smoke Breath Analyzer

The Smokerlyzer devices that already exist today are all designed to measure carbon monoxide (CO) in a smoker's breath, helping with smoking cessation. The device provides instant results shown in exact ppm and %COHb. For professionals, these devices offer a biochemical method to assess a person's smoking status. For smokers, the Smokerlyzer serves as a motivational tool, providing a visual way to track their progress and encourage them to quit. This is a personal CO device designed to assist people in quitting smoking, one breath at a time. It measures the CO in breath and shows the results in the app, offering visual motivation to help quit. The app pairs with the device to track the progress in real-time and provide continued encouragement throughout the journey. Study shows the diagnostic accuracy of the test is 82.89%, which shows the proportion of correct test results [7].

The detection principle includes an electrochemical sensor, which assess CO in the initial part of expiration. The subject exhales through a disposable pipe which fits to the machine through a one-way valve and the sample is captured by diffusion. The standard values provided by 'Bedfont' includes: eCO levels of <6 ppm which corresponds with COHb% concentration of <1.59% which indicates the normal level (Green zone). The range of eCO between 7 to 10 ppm or COHb% between 1.75% to 2.23% indicates a light smoker or a passive smoker or a smoker breathing in poor air quality (Yellow zone). The range of eCO between 11 to 30 ppm or COHb% between 2.39% to 5.43% indicates a regular smoker (Red zone) [7]. Individuals in the yellow or red zone were given the standard peak flow meter test, which measures their ability to exhale air from the lungs. This test can serve as a screening tool for conditions like asthma and chronic obstructive pulmonary disease (COPD) before a formal diagnostic assessment using spirometry. The peak expiratory flow rate (PEFR) is typically used to evaluate airway narrowing prior to an asthma attack. COPD, which is primarily caused by smoking tobacco, is influenced by the number of pack-years smoked and the duration of smoking, both of which contribute to the disease's severity and the progressive loss of lung function due to damage to the alveol [8].

The Use of Smoke Breath Analyzer

The UK smoking cessation guidelines for midwives recommend using exhaled CO levels as a screening tool to identify and refer pregnant women who smoke to specialized smoking cessation services. The breath CO analyser is a device that measures the amount of carbon monoxide in a single exhaled breath, automatically calculates the percentage of carboxyhaemoglobin in the mother's blood, and estimates the carboxyhaemoglobin levels in the baby's blood. The results are shown in precise parts per million (ppm) for CO and as a percentage for carboxyhaemoglobin [9].

Smoke breath analyzers measure CO levels in exhaled breath, offering a quick, non-invasive way to assess a person's smoking status. Unlike blood tests, which can be expensive and time-consuming, breath analyzers provide real-time results with minimal discomfort. This makes them especially valuable in routine clinical settings and for tracking progress in smoking cessation. The use of CO breath analyzers has been shown to support individuals in reducing smoking. The results indicated that receiving regular feedback from CO breath measurements increased motivation and improved success rates in quitting smoking. The immediate feedback helps individuals understand the direct impact of smoking on their health, strengthening their commitment to quitting [10].

Interpretation

The smoke analyzer device measures CO levels in parts per million (ppm). A reading of 9 ppm is typically considered the highest acceptable CO level in the breath of someone who claims not to smoke, although CO from airway inflammation in conditions like COPD can sometimes reach up to 11 ppm. The National Institute for Health and Care Excellence advises that a CO level of less than 10 ppm, measured four weeks after the quit date, should confirm success in quitting smoking. However, this doesn't mean treatment should be discontinued after four weeks. Heavy tobacco use, water pipe smoking, or smoking other substances like cannabis can lead to higher CO levels. Properly interpreting these readings can help guide conversations with smokers and inform decisions about further interventions [11]. The more a person smokes, and the more intensely they inhale or 'drag' on their cigarette, the higher their CO reading will be. CO monitoring therefore assists to determine the level of nicotine dependence and provides the smoker with visible and real-time proof of the effects of smoking on their body. This can help to motivate the person during a quit attempt by charting changes in CO levels over a period of time.

What is CO?

CO has long been known as a "silent killer" because of its ability to bind hemoglobin (Hb), leading to reduced oxygen carrying capacity of Hb, which is the main cause of CO poisoning (COP) in humans [12]. CO is a colorless, odorless, tasteless, and non-irritating gas produced by the combustion of gasoline, wood, charcoal, propane, and other fuels. CO competes with oxygen to bind to hemoglobin (Hb), forming carboxyhemoglobin (COHb), which shifts the oxyhemoglobin dissociation curve to the left. This reduces the blood's ability to carry oxygen and limits oxygen delivery to peripheral tissues. CO exposure occurs in various settings. Inhalation of CO from tobacco smoke is a significant source of exposure for smokers. Additionally, environmental exposure may occur in areas with high levels of traffic emissions or industrial pollution. In extreme cases, CO poisoning can occur from faulty heating systems or from accidents involving gas-powered engines. CO is generated from the incomplete combustion of hydrocarbons and is a by-product of tobacco smoking. Chronic cigarette smokers frequently have COHb levels as high as 10% [13].When CO is inhaled, it enters the bloodstream and attaches to hemoglobin with an affinity about 200-250 times stronger than oxygen. This prevents oxygen from binding to hemoglobin, reducing the amount of oxygen that reaches tissues and organs. As a result, the body suffers from hypoxia (oxygen deficiency), which can cause various harmful effects, particularly in critical organs like the brain, heart, and lungs [14].

CO Effect Does Have On The Body

CO has significant effects on the human body, primarily through its ability to bind with hemoglobin, forming COHb. This reduces the oxygen-carrying capacity of the blood and disrupts the delivery of oxygen to tissues and organs. CO binds to hemoglobin more strongly than oxygen, which disrupts the effective transport of oxygen in the body. The severity of its effects depends on the level of exposure, with mild symptoms like headaches and dizziness occurring at low levels, and more serious effects such as confusion, unconsciousness, or even death at higher levels [14].

Tissue hypoxia caused by CO leads to increased vascular permeability, fluid accumulation in the interstitial spaces, and reduced circulating blood volume, which can affect multiple organs. To diagnose CO poisoning, three clinical factors should be present: symptoms consistent with poisoning, a recent history of CO exposure, and elevated levels of COHb. The primary treatment for CO poisoning is high-flow normobaric oxygen therapy, which should be administered as soon as possible [15]. Studies have shown that long-term smokers with elevated COHb levels experience cognitive decline and may have an increased risk of neurodegenerative diseases such as Alzheimer's and Parkinson's disease. A 2023 study found that chronic exposure to CO from tobacco smoke can impair neuroplasticity, resulting in diminished brain function over time [16]. Moreover the cardiovascular impact of CO is also a significant concern. A 2022 study in Circulation Research explored how CO exposure from smoking is linked to a higher risk of atherosclerosis (plaque buildup in the arteries). Increased levels of COHb lead to oxidative stress, inflammation, and damage to the blood vessel lining, all of which speed up the progression of cardiovascular conditions like coronary artery disease [17].

A study presents a case of significantly elevated COHb and polycythemia resulting from tobacco smoking and offer a review of the literature on elevated COHb levels in smokers. COHb levels in regular cigarette smokers typically range from 4.2% before smoking to 8.6% after smoking. A heavy cigarette smoker who experienced CO toxicity symptoms on two occasions had COHb levels between 21.8% and 24.2%. Cigar smokers have been reported to have COHb levels ranging from 13.0% to 38.6% in various case studies. Waterpipe or "hookah" smokers usually have COHb levels around 10.1% with a +/- 2.5% variation, and higher levels associated with CO toxicity symptoms are commonly reported. In some cases, waterpipe smokers have had COHb levels as high as 39.2% after smoking [18].

Why CO?

CO is a non-irritating gas that is present in the environment at low concentrations and has a similar molecular weight to air. CO has a strong affinity for binding to ferrous heme-containing proteins, such as hemoglobin (90%) in the blood, and less frequently to myoglobin and Cytochrome C Oxidase in tissues (10%). CO competes with oxygen for binding to hemoglobin, forming COHb, which shifts the oxyhemoglobin dissociation curve to the left, reducing the blood's ability to carry oxygen and impairing oxygen delivery to peripheral tissues. However, the bond between CO and hemoglobin is reversible. COHb levels are considered abnormal and may produce symptoms if COHb level $\geq 2\%$ in nonsmokers and $\geq 10\%$ in smokers [19].

Measuring CO in an individual's breath is a fast, non-invasive, and affordable way to assess their smoking status. Higher CO levels typically indicate greater nicotine dependence. However, smoking levels can also be affected by psychosocial, behavioral, and biological factors. The CO monitor is an independent clinical tool that offers valuable evidence for diagnosing and treating patients with tobacco dependence. After holding their breath, the amount of CO in the exhaled air is strongly correlated with COHb levels. Other biomarkers like thiocyanate (SCN), cotinine, nicotine, and COHb are used to measure the byproducts of inhaled cigarette smoke in serum, saliva, or urine. However, these methods can be time-consuming, costly, and do not provide immediate results [20].

Other Volatile Organic Compounds in Exhaled Breath of Cigarette

In a study of exhaled breath analysis revealed that pyridine, 2-methylfuran, and benzene were detected more frequently in smokers, while 2-methylfuran and pyridine were present in all cigarettes users and heated tobacco products (HTPs). The levels of 2-methylfuran, benzene, isoprene, pyridine, toluene, and pyrrole in exhaled breath were significantly higher after smoking compared to before. Based on measured CO levels, it was difficult to differentiate between nonsmokers, HTP users, and electronic cigarette users. These findings suggest that 2-methylfuran and pyridine could potentially serve as indicators of smoking status. Furthermore, secondhand smoke exposure might be assessed by detecting VOCs in the exhaled breath of HTP users. However, additional research is needed to confirm these possibilities [21].

A study found that in some cases, nicotine was not detected in smokers, leading to confusion between smokers and non-smokers. Nicotine was found in the breath of 64% of cigarette smokers, with an average amount of 143 ± 31 pg from a 5-liter breath sample collected within an hour after smoking. The successful use of the capillary micro-extraction of volatiles (CMV) sampler to concentrate breath samples and distinguish smokers from non-smokers demonstrates its potential for future applications, such as detecting marijuana smokers' breath for impaired driver management [22].

Effectiveness In Detecting Tobacco Smoking

Measuring CO levels offers an impartial way to gauge smoking habits. It's generally preferred to assess CO concentration through exhaled air rather than blood samples because it's less invasive and easier to perform. This principle supports the use of CO breath analyzers to detect smoking behavior. Jarvis et al. and others have suggested that the availability of reliable, affordable CO analyzers could make them useful in healthcare and health education environments [23]. The accuracy and effectiveness of the breath CO test are also supported by studies suggesting that the results are highly reproducible and correlate well with self-reported smoking status. This is crucial for its application in health education and clinical practice, where rapid and reliable feedback can encourage smoking cessation and help monitor progress [24]. A study published in Tobacco Control (2021) evaluated the use of CO breath analyzers in smoking cessation programs and found that the Smokerlyzer, a widely used device, provided accurate and reproducible results. The study reported that CO levels in exhaled breath correlated well with the number of cigarettes smoked, offering an effective means for clinicians to objectively assess smoking habits. This correlation was particularly useful in monitoring the success of smoking cessation interventions and providing immediate feedback to patients [25].

Another study published in Nicotine & Tobacco Research (2020) confirmed the utility of CO breath analyzers in distinguishing smokers from non-smokers, with high sensitivity and specificity. The research highlighted that CO breath tests are more sensitive in detecting smoking habits than self-reported data alone, as smokers often underreport their tobacco use. Additionally, the breath test analyzer showed promise in identifying light smokers, who might otherwise be difficult to assess using other methods [26]. Further, in a 2022 review published in BMC Public Health, researchers concluded that CO breath analyzers are particularly effective in community health settings where quick, non-invasive, and cost-effective tools are needed to assess smoking status. The review emphasized the role of these devices in both clinical and educational contexts, where they help not only in detecting smoking behavior but also in providing real-time data to patients and healthcare providers. Smoke breath analyzers are also cost-effective compared to other diagnostic methods, such as blood tests or biochemical analysis of nicotine metabolites. It is emphasized that low-cost CO breath analyzers could be widely implemented in public health campaigns, smoking cessation clinics, and primary care settings. These devices are accessible, easy to use, and require minimal training, making them suitable for both healthcare providers and patients [23].

Barriers to the Use of Smoke Breath Analyzers

Although CO breath analyzers offer clear benefits, one major challenge is the lack of awareness among both healthcare providers and the public about their effectiveness. A study published in 2021 revealed that many clinicians are unaware of the potential of CO breath testing as a tool for monitoring smoking and aiding in cessation. Although CO breath analyzers are generally cost-effective compared to other diagnostic methods, the initial purchase and maintenance costs can still be a barrier, particularly for healthcare providers in resource-limited environments. A 2020 review in Public Health Reports highlighted that many healthcare systems are hesitant to invest in new technologies without clear evidence of their cost-effectiveness in improving long-term health outcomes. The study noted that while CO breath testing is cheaper than blood tests or more complex diagnostics, financial constraints still limit its widespread use [27].

Effective use of CO breath analyzers requires specialized training in interpreting results and applying them to patient care. A 2022 study in Nicotine & Tobacco Research found that healthcare providers often lack the necessary training to use breath CO measurement devices effectively. Without formal education on these tools, many clinicians either avoid using them or don't know how to incorporate them into smoking cessation counseling [26]. This knowledge gap contributes to their underuse, as providers may prefer more familiar methods or avoid unfamiliar ones. Some patients may also be reluctant to undergo CO breath testing. A 2021 study in Tobacco Use Insights explored patient attitudes toward smoking cessation tools and found that some smokers feel uncomfortable with breath analyzers, possibly due to the stigma associated with smoking or the fear of being judged for their tobacco use [28]. This reluctance may be more pronounced in settings where patients are not well-informed about the benefits of these devices in improving their health.

In a study on Carbon Monoxide Assessment in Expired Air using a Portable Smokerlyzer Device that uses only one breath for sampling, the diffusion process may not be able to capture the asymptotic value with only one breath (residual effect from the subject's previous reading). The machine used, EC50, showed a second value that was higher than the first value. Ideally, two consecutive readings should be taken. It can be concluded that there is a possibility of bias in the results due to this [7]. In addition, measurement bias can be caused by a number of everyday activities that can expose people to CO, including secondhand smoke, environmental pollution, and occupational exposure, with smoking being the most common factor contributing to high exposure levels. Occult CO poisoning, such as that caused by a malfunctioning home heating system or car exhaust system, is another source of high CO exposure; however, this may only partially account for high levels of CO in the breath [29].

Future Research Directions

VOCs are produced as by-products of metabolism, so alterations in underlying physiological processes are reflected in the composition of exhaled VOCs. Characteristic changes in VOC profiles have been associated with various diseases, including cancer, enabling the potential for non-invasive detection even in patients presenting with subtle or vague symptoms. Analysis of exhaled VOCs can provide insights into underlying conditions such as cancer, as well as infectious or inflammatory diseases. Looking forward, non-invasive breath testing holds significant promise for transforming early disease detection, particularly in surgical and primary care settings [30].

Furthermore, the use of this CO detection device could have broader benefits beyond cigarette monitoring. It could be clinically useful in personalized healthcare, such as in diagnosing and managing respiratory conditions like asthma and sleep apnea, replacing the invasive measurements currently used by arterial blood gas analysis [31]. Non-invasive and continuous monitoring is essential in the diagnosis and treatment of medical diseases such as for intraoperative monitoring as well as the diagnosis and treatment of respiratory and metabolic diseases, maintaining hemic homeostasis by providing a bicarbonate buffer system [32].

CONCLUSION

The recommendation to use smoke breath analyzers is grounded in their accuracy, ease of use, and broad applicability in both clinical and public health contexts. These devices are particularly valuable for monitoring smoking behavior, offering real-time feedback, and supporting smoking cessation efforts. Given their low cost, non-invasive nature, and effectiveness, CO breath analyzers should be widely implemented in healthcare settings to improve smoking cessation outcomes and reduce smoking-related health risks. The lack of widespread use of smoke breath analyzers, despite their effectiveness in detecting smoking habits and assisting with smoking cessation, has been a topic of concern in recent literature. To overcome the barriers preventing the widespread use of smoke breath analyzers, a multifaceted approach is needed that targets education, cost-efficiency, integration into healthcare systems, and training for healthcare providers.

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