Jurnal Sains Teknologi & Lingkungan
Available online http:// jstl.unram.ac.id
ISSN: 2477-0329, e-ISSN: 2477-0310
Terakreditasi Kemenristek-DIKTI SINTA 4
Nomor: 225/E/KPT/2022

Vol. 10 No. 4 pp: 617--622
Desember 2024
DOI https://doi.org/10.29303/jstl.v10i4.728

Research Articles

VOCs (Volatile Organic Compounds) Concentration Measurement in Human-Exhaled Breath - A Preliminary Study

Measurement of VOC Levels in Human-Exhaled Breath

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Manuscript received: 15-11-2024. Accepted: 17-12-2024

ABSTRACT

VOC is a group of organic compounds that easily evaporate into the atmosphere and have various impacts on human health and the environment. Human exhaled breath and VOC is related to each other. The concentration of VOC differs from an abnormal condition to other abnormalities. However, there is limited information or study about VOC concentration in human exhaled breath. In line with this, this study aims to develop a VOC meter or a measurement system using a CCS811 sensor for human exhaled breath. This study used a CCS811 sensor, a microcontroller, and a suction pump installed inside a sensor box. The system was calibrated using filtered and non-filtered air. The system was tested using varying flow rates. At the final test, the system was tested to measure VOC levels in human exhaled breaths. The results show that the VOC measurement system can measure VOC levels in different air conditions for both filtered and non-filtered air. The use of different flow rates influences the system's performance. The highest sensitivity level is obtained at 0.7 m/s of the flow rate of the suction pump. The system was also able to measure VOC concentrations of the human exhaled breath with concentrations of 0 ppb to 1156 ppb. The VOC concentrations of human exhaled breath depend on many factors that should be further analyzed, including the medical treatment history, food consumption, placebo effect, and many other parameters.

Keywords: air; exhaled breath; measurement system; sensor; volatile organic compound

INTRODUCTION

All people need fresh air to live in their daily lives for breathing mechanisms. This mechanism needs fresh oxygen with no pollution. In this sight, fresh air plays an important parameter in regulating life balance and a good ecosystem. Normal or fresh air is also related to the ambient air substances in the atmosphere. There are 78% nitrogen, 21% oxygen, 0.93% argon, and several other gases such as helium, neon, and carbon dioxide. Air can also contain particles, pollutants, and microorganisms (Suhartawan *et al*., 2024)

Air pollutants become a serious problem related to air quality and health impacts. Air pollutants have liquids, solids, and dangerous gases generated from many sources and reduce air quality levels (Manisalidis *et al*., 2020; Wardoyo *et al*., 2020). These pollutions, whether gaseous or particulate emissions, increase the risk of health problems and environmental abnormalities. Based on a study, air pollution has been the world's largest contributor to environmental damage and a decline in human health (Mebrahtu *et al*., 2023). Air pollution can be classified as VOC (volatile organic compound), fine particle, coarse particle, carbon dioxide, carbon monoxide, and many other gasses (Fetisov *et al*., 2023)

Specific to VOC, this pollution is a group of organic compounds that easily evaporate into the atmosphere and have various impacts on human health and the environment. VOC is a fundamental parameter in forming tropospheric ozone and secondary organic aerosols in the Earth (Jia *et al*., 2019). This emission can be generated from various combustion processes, such as power plants, fossil fuel processing, oil refineries, biomass burning, and transportation. As confirmed in a previous study, excessive exposure to VOCs relates to air quality management problems. Furthermore, many sectors of the emission sources generate many types of VOCs and contribute to the formation of ozone and other emissions (Schnelle Jr & Brown, 2016).

A previous study shows that long-term exposure to VOCs can cause health problems such as colds, coughs, and sore throats (Maung *et al*., 2022) and more serious health problems such as internal organ damage and cancer. Aldehyde and benzene, as the types of VOCs, are carcinogens and are very dangerous for human health (Seinfeld & Pandis, 2016; Tiwari *et al*., 2020). Interestingly, there are more than 2000 types of VOCs, in which more than 1000 types are easily measured in human exhaled breath. VOCs in human exhaled breath are also observed as an inflammation condition (Zheng *et al*., 2024).

According to a previous study, human exhaled breath and VOC is related to each other. The concentration of VOC differs from an abnormal condition to other abnormalities, such as COPD (chronic obstructive pulmonary disease) and asthma (Hintzen *et al*., 2024). The increasing VOC level in the exhaled breath can also be related to a specific disease, such as ulcers due to metabolic changes (Yakob *et al*., 2021).

As a mitigation requirement or as pre-clinical equipment, there is a need to develop a VOC meter that can measure VOC concentration in human exhaled breath. For this purpose, a CCS811 sensor is a potential sensor module that is sensitive to volatile gas. This digital-type sensor is made of a metal oxide-type sensitive material with digital data via I2C (inter-integrated circuit) (Kim, 2021). Hence, the existence of this sensor and VOC substance in human exhaled breath becomes a specific background of this study. This study aims to develop a VOC meter or a measurement system using a CCS811 sensor for human exhaled breath.

MATERIALS AND METHODS

System development and Calibration

This study was conducted at the Instrumentation and Biophysics Laboratory, University of Mataram. This study used a CCS811 sensor that was tested and calibrated using clean air by turning on the system for 20 minutes (initial burning time). This clean air was generated using a HEPA filter with a constant flow rate. The sensor was installed inside a sensor box and connected to a microcontroller and a suction pump (Table 1, Figure 1). The calibration process was also conducted using different flow rates, v_1, v_2, v_3, and v_4 to obtain the best performance. For this test, the air sample was injected into the exposure chamber for 100 seconds and exposed to the system. This test was repeated three times (n = 3) (Widhowati et al., 2021).

Table 1. Flow rate variations for calibration

Variables	Values
flow rate (m/s)	0.5; 0.6; 0.7; 0.8
input area (m^2)	A2
measurement parameters	
repeatition	3
temperature (°C)	25-26
injection time (s)	100

Exhaled Breath Measurement

Exhaled breath measurement was conducted for 30 samples (n = 30 samples). The samples were chosen as the members of the laboratory (15 males - 15 females). The samples also filled out the questionnaire related to their health history and food/drink consumption.

Figure 1. System design using a sensor and a microcontroller (Budianto et al., 2021)

Analisis Data

The data was interpreted as the mean value and analyzed using an ANOVA test (p-value). The calibration data was interpreted in an equation (Equation 1).

$$y = ax + b \quad (1)$$

The determination coefficient (R^2) was also analyzed.

RESULTS AND DISCUSSION

The measurement data of the system using filtered and non-filtered air are shown in Table 2. It can be seen that the system performs well in measuring VOC concentrations whether using a HEPA filter or not. The use of the constant flow rate (0.5 m/s) indeed makes a laminar flow or vortex that generates a constant VOC concentration. Table 2 shows that there is a significant difference between filtered and non-filtered air. These results interpret that non-filtered air can contain certain VOC levels (in the unit of ppb). Cleaner air has a lower VOC concentration.

Table 2. Calibration data using filtered and non-filtered air inside an exposure chamber

Time (s)	Non-filtered Air (ppb)	Filtered Air (ppb)
0	11	1
10	12	1
20	11	1
30	10	2
40	10	1
50	10	2
60	9	1

Time (s)	Non-filtered Air (ppb)	Filtered Air (ppb)
70	9	2
80	8	2
90	9	2
100	11	2
Mean	10±1	2±1

Figure 2 shows the data variations under different flow rates.

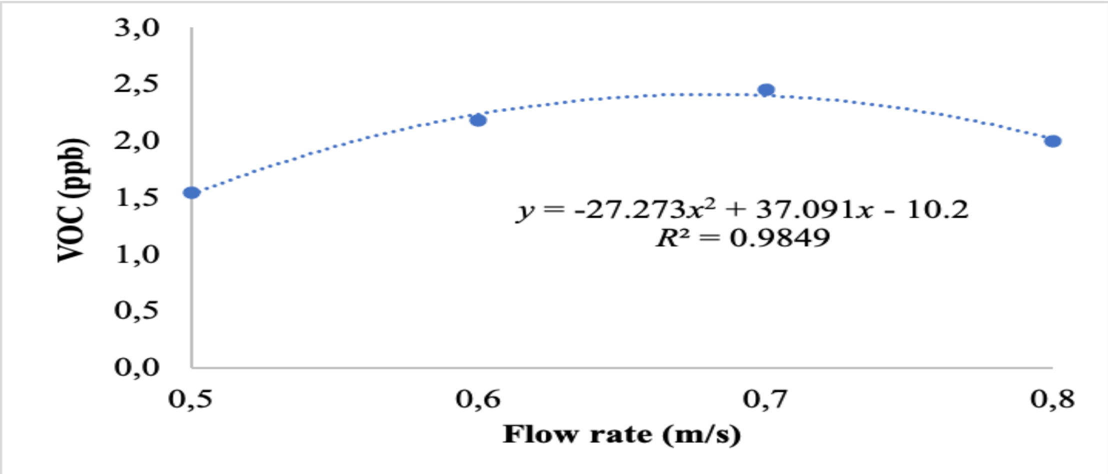

Figure 2. The VOC concentrations were measured from the system in different flow rate levels.

Figure 2 interprets that the maximum flow rate (0.8 m/s) has low performance, with a mean concentration of 2.0±0.9 ppb. Similarly, the minimum flow rate (0.5 m/s) has also low performance, with an average VOC concentration of 2.2±0.6 m/s. The best value is obtained at 0.7 m/s of the flow rate. The approach function to predict the trendline is obtained at a 2nd order of a polynomial function ($y = -27.273x^2 + 37.091x - 10.2$). This function has a determination coefficient of $R^2 > 0.98$, showing a good correlation between the flow rate and the VOC concentration.

Table 3. The VOC concentrations were measured from human exhaled breath.

ID	VOC (ppb)	
	Female	Male
1	120	97
2	9	54
3	3	63
4	97	55
5	455	32
6	1156	12
7	950	0
8	554	19
9	42	25
10	40	87
11	2	112
12	4	190
13	5	555
14	12	232
15	1	21

Finally, the system was also used to measure directly the VOC concentration from the exhaled breath samples. As interpreted in Table 3, human exhaled breath consists of different VOC concentrations. The minimum value is only 0 ppb, while the highest value is 1156 ppb. According to the sensor datasheet, these values are correct as the sensor span (1156 ppb), with the range of 0-1156 ppb.

The difference between each sample can be related to the human condition. Moreover, the existence of different temperatures and flow rates, as well as the metabolism, may influence the results. The non-laminar flow rate may change the concentration, as found in the Brownian motion (Wardoyo & Budianto, 2017).

CONCLUSION

The study data show that the sensor can measure VOC levels in different air conditions, for both filtered and non-filtered air. The use of different flow rates influences the system's performance. The highest sensitivity level is obtained at 0.7 m/s of the flow rate of the suction pump. The system was also able to measure VOC concentrations of the human exhaled breath with concentrations of 0 ppb to 1156 ppb. The VOC concentrations of human exhaled breath depend on many factors that should be further analyzed, including the medical treatment history, food consumption, placebo effect, and many other parameters.

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