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Effectiveness of TiO_2-coated stainless steel mesh reactor with UV-LED on the reduction of cigarette smoke pollutants in a closed room

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Abstract

Indoor air pollution, particularly from cigarette smoke, contains harmful Total Volatile Organic Compounds (TVOC) that poses significant health risks. This study aims to evaluate the effectiveness of a Photocatalytic Oxidation (PCO)-based air purification system utilizing a Titanium Dioxide (TiO_2)-coated stainless steel mesh reactor and Ultraviolet Light Emitting Diode (UV-LED) sources at 365 nm and 390 nm wavelengths. The methodology involved synthesizing TiO_2 sol and immobilizing it onto a stainless steel 304 mesh substrate via a dip-coating technique. Performance testing was conducted in a closed room (volume approx. 136 m³) where smoke from two cigarettes was introduced as the pollutant source. TVOC concentrations were monitored every 5 minutes at five distinct measurement points (center and corners) over a 2-hour period to assess spatial distribution and degradation performance. The results demonstrated that the PCO system with a 365 nm UV-LED reduced the average TVOC concentration from 0.78 ppm to 0.33 ppm, achieving a reduction rate of 57.69%. Meanwhile, the 390 nm UV-LED system decreased the concentration from 0.86 ppm to 0.32 ppm, corresponding to a 62.8% reduction. While the difference in UV-LED wavelength did not significantly alter the photocatalytic performance, light intensity and initial pollutant concentration were found to influence the degradation rate. Overall, the TiO_2-coated stainless steel mesh reactor proved to be an effective solution for reducing indoor cigarette smoke pollutants.

Keywords:
Air purification, cigarette smoke, photocatalytic oxidation, titanium dioxide, TVOC.

1 Introduction

Indoor air quality is crucial to building occupants' health and comfort [1]. More than 87% of people spend time indoors [2], making pollution controls an increasing concern. Specifically, cigarette smoke introduces over 7,000 toxic substances [3], including benzene and formaldehyde, which pose significant health risks ranging from respiratory disorders to genotoxicity [4], [5], [6]. Despite widespread non-smoking regulations, high concentrations of these pollutants persist in designated smoking rooms (e.g., in airports and malls) and hospitality venues like cafes or private offices where smoking is still permitted. In such confined environments, natural ventilation is often insufficient. Therefore, developing effective air purification systems is essential to manage pollution levels in these specific areas and prevent smoke leakage into non-smoking zones.

Several studies have been conducted to reduce the harmful effects of cigarette smoke. Among them is the use of activated carbon filters [7], and filters enriched with metal ions complexed with porphyrin rings [8] to utilize the natural ability of the aloe-in-law plant to absorb Volatile Organic Compounds (VOCs) in the air [9].

In addition, photocatalysis technology has received widespread attention due to its ability to decompose organic pollutants through oxidation reactions triggered by light [10]. Titanium Dioxide (TiO_2) is one of the most widely researched and used catalysts in photocatalysis [11]. Photocatalysis with titanium mesh filters coated with TiO_2 decomposes harmful components in cigarette smoke, including VOCs such as benzene and toluene [12]. In addition, TiO_2-coated polylactic acid is also used in indoor air purifier applications. This study noted that in Poly-Lactic Acid (PLA)/TiO_2 composite films, TiO_2 in the anatase phase was an effective photocatalyst and successfully degraded five ppm of benzene within 147 minutes [13]. Another study showed that using PLA/TiO_2 could reduce the concentration of HCHO by 21.76% within 20 minutes [14].

To increase the effectiveness of TiO_2, adding the proper support or substrate can increase its photocatalytic capacity and efficiency [15]. Stainless steel mesh is one of the promising substrates for this application. The advantages of stainless-steel mesh are mechanical strength, corrosion resistance, and the ability to evenly distribute the TiO_2 layer evenly, thus allowing better interaction between pollutants and catalysts [16]. Stainless steel mesh is also more affordable and readily available than titanium mesh. Stainless steel 304 in the form of woven wire mesh has been used in oil and water separation applications [17], removal of acetone, acetaldehyde, and isopropanol gas [18], and degradation of methylene blue in wastewater samples [19].

This study aims to evaluate the effectiveness of a photocatalytic oxidation-based indoor air purifier using a stainless steel 304 woven wire mesh 50 reactors coated with TiO_2. The air purifier's effectiveness is measured based on the concentration of pollutants in the room before and after the reactor is turned on. Cigarette smoke was used as a sample of common indoor organic pollutants, and it was chosen as a target to assess the performance of this device. The UV-LED wavelength difference was also evaluated to determine the photocatalytic performance.

2 Research methods/materials and methods

2.1 Design of Air Purifier Photo-Catalytic Oxidation (AP PCO)

The AP PCO contains four separate parts as shown in Fig. 1: (1) the bottom casing, which serves as a container for adapters and plugs; (2) the tray for placing TiO_2-coated SS mesh; (3) the tray for placing UV-LED; (4) the tray for placing HEPA filters; (5) the tray for placing fans with the specification: power: 18 W, voltage: 220 V, frequency: 50 Hz, noise level: 42 dB and airflow capacity: 195 m²/h.

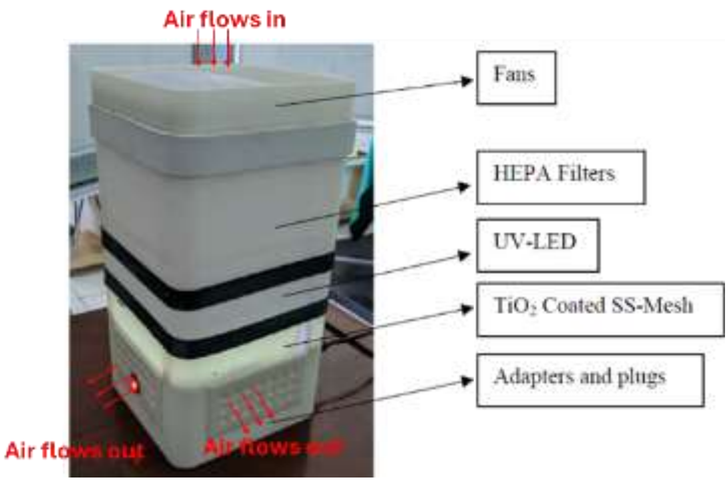

Fig. 1. Air purifier PCO.

2.2 PCO reactor

2.2.1 Substrate

The substrate used is stainless steel mesh (type 304 woven wire mesh 50), as shown in Fig. 2, cut to 80 mm × 80 mm and as many as

20 sheets. The substrate coated with TiO_2 is mounted on a tray of 5 sheets per box.

(a) (b)

Fig. 2. Stainless steel mesh substrate (304 woven wire mesh 50) (a) cut to 80×80 mm (b) mounted on the tray.

2.2.2 Photocatalyst material

The photocatalyst material used is Titanium Oxide (P25 Degussa). TiO_2 effectively breaks down pollutants into safer molecules such as CO_2 and H_2O [20], but also has the advantages of low cost, chemical stability, and environmental friendliness [21].

Synthesize TiO_2 on the surface of Stainless-Steel (SS) mesh. The SS-mesh substrate will then be coated with TiO_2 through dip-coating with TiO_2 sol. The TiO_2 coating technique on SS-mesh is: (1) synthesize TiO_2 sol by acidifying 500 mL of distilled water to pH 3 using a 1 M nitric acid (HNO_3) solution. Next, mix 1 g of TiO_2 P25 Evonik into 500 ml of pH three aquadest; (2) add Tetraethyl Orthosilicate (TEOS) 98% to the mixture, up to 0.5 mL. Then, stir the mixture using a magnetic stirrer for 5 minutes; (3) the mixture was stirred in an ultrasonic cleaner for 15 minutes. The sol that had formed was then allowed to stand for 1 day to separate the sol parts that precipitated and dispersed evenly in distilled water; (4) the sol that has been allowed to stand is then taken, the dispersed part (the top) is coated on SS-mesh with the soaking technique for 5 minutes. Next, the SS-mesh coated with TiO_2 is dried with a hair dryer for 15 minutes.

2.2.3 UV light intensity measurement

This tool test uses UVA LEDs that have different wavelengths. UVA LED has a range from 315 to 400 nm [22]. UV light intensity at 365 nm and 390 nm wavelengths was measured using an ML8511 sensor to detect light at 280 nm-390 nm wavelengths. The sensor is placed in the TiO_2-coated SS-mesh tray surface facing towards the UV-LED and connected to Arduino UNO (Fig. 3).

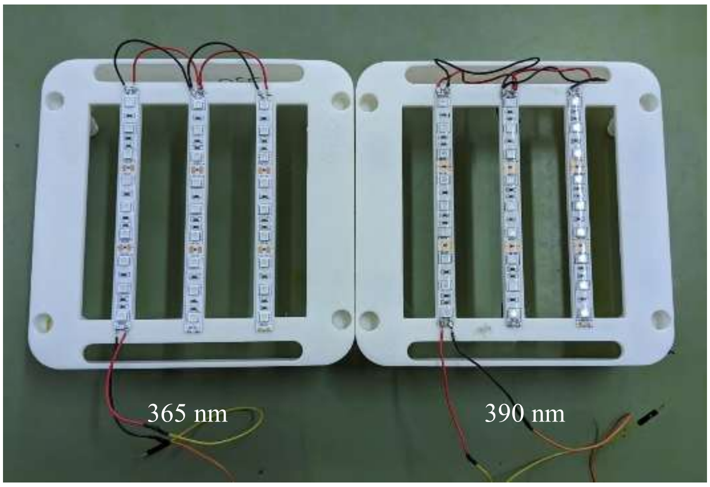

Fig. 3. UV-LED mounted on the tray.

Data was taken every 1 second for 1 minute. Based on Table 1, it is observed that the background intensity (when the UV-LED is off) for wavelengths of 365 nm and 390 nm is the same, namely 0.03 mW/cm². According to the ML8511 sensor datasheet, when there is no UV light, the output voltage is 0.99 V and the light intensity is 0 mW/cm² [23].

Table 1. Measurement results of UV-LED light intensity at 365 nm and 390 nm

Light intensity	UV-LED 365 nm	UV-LED 390 nm
Background UV (off)	0.03 mW/cm²	0.03 mW/cm²
UV-LED active (on)	0.22 mW/cm²	0.44 mW/cm²

After the UV-LED is activated (on), the light intensity increases significantly. For the 365 nm UV-LED, the recorded intensity is 0.22 mW/cm², while for the 390 nm UV-LED it is 0.44 mW/cm². This means that the 390 nm UV-LED produces nearly twice the intensity compared to the 365 nm UV-LED.

This difference indicates that the output power of the 390 nm UV-LED is stronger than that of the 365 nm UV-LED, which may affect the effectiveness of the photocatalytic process, particularly in terms of TiO_2 catalyst activation.

2.2.4 Measurement of pollutant concentration

TVOC concentration was measured for 2 hours in a room measuring 5.25 m × 8.05 m × 3.22 m with a room area of 136.25 m^2. Data was taken every 5 minutes using an Extech Instrument VFM200. This tool has a measurement range of TVOC 0.00-9.99 ppm and HCHO 0.00-5.00 ppm and is certified to ISO 9001 standards. The measurement method refers to the AHAM portable air purifier performance measurement method [24]. Five measurement location points are in the center and the room's four corners. The illustration as show in Fig. 4.

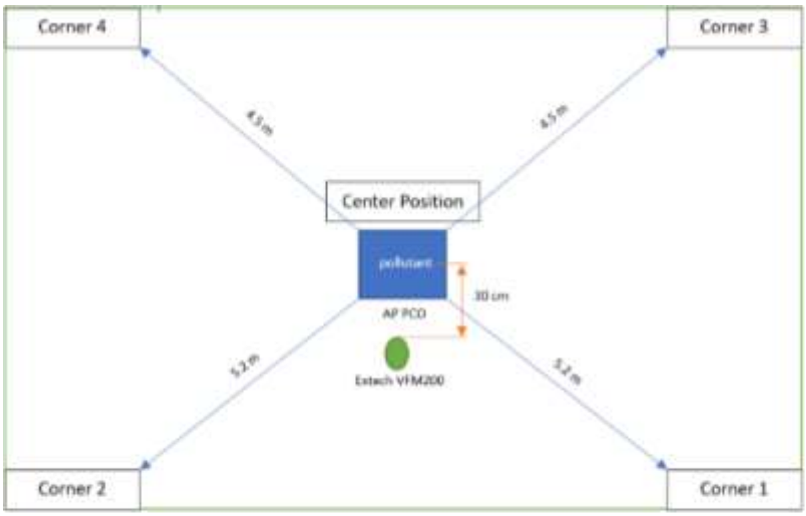

Fig. 4. Illustration of 5 measurement location points in the room.

The measurement scheme as shown in Fig. 5.

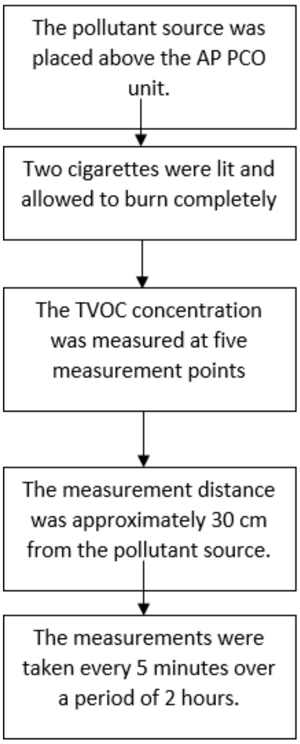

Fig. 5. TVOC concentration measurement scheme.

TVOC reduction percentage (R) is calculated using the Eq. (1) [25], where C_0 is the initial concentration of TVOC (at $t = 0$), and C is the TVOC concentration at time t.

$$\boldsymbol{R} = \left(\mathbf{1} - \frac{C}{C_0}\right) \times 100\% \qquad (1)$$

3 Results and discussion

3.1 Reduction results of cigarette smoke pollutants at 365 nm UV-LED

Fig. 6 and Table 2 present the comparison of TVOC concentrations between the baseline condition (without pollutants) and the condition after the introduction of cigarette smoke. The data reveals a significant surge in pollutant levels when cigarette smoke is introduced.

While the baseline air quality remained relatively stable with negligible TVOC levels, the combustion of cigarettes caused an immediate and sharp spike in concentration (reaching approximately 0.78 – 0.86 ppm). This phenomenon demonstrates the high volatility and rapid diffusion of cigarette smoke emissions in a closed environment (136 m³). Even a limited source of pollution (two cigarettes) was sufficient to deteriorate the indoor air quality drastically, raising the TVOC levels far above the ambient background. This stark contrast serves as a critical validation for the experimental setup, confirming that the elevated concentrations are solely attributed to the smoke introduction and underscoring the urgency for effective remediation using the PCO system.

The largest TVOC concentration is shown in Corner 2, where corner point 2 of the room has a pile of wooden tables. This is because wooden tables also contain VOCs, including formaldehyde and acetaldehyde [26].

The next test involved introducing pollutants in the form of cigarette smoke into a closed room. Two cigarettes, each containing 14 mg of tar and 1.0 mg of nicotine, were lit and allowed to burn completely. Afterward, TVOC concentration measurements were taken at five different locations. As shown in Table 2 at the center position, the smoke from two cigarettes increased the TVOC concentration from 0.45 ppm to 0.80 ppm. This indicates that the introduction of cigarette smoke into the room leads to an increase in TVOC concentration.

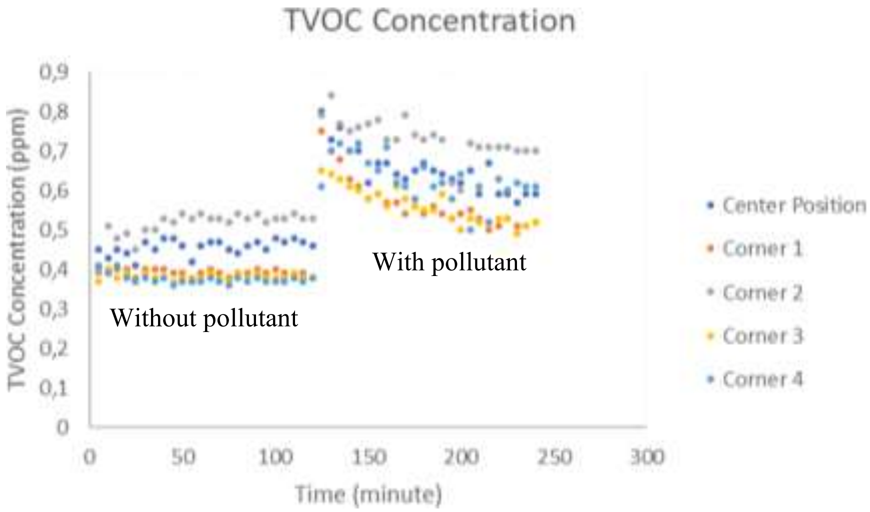

Fig. 6. TVOC concentration without pollutants and with cigarette smoke.

Table 2. TVOC concentration without pollutants and with cigarette smoke

	Center position	Corner 1	Corner 2	Corner 3	Corner 4
Without pollutant	0.45 ppm	0.38 ppm	0.53 ppm	0.37 ppm	0.38 ppm
With pollutant	0.80 ppm	0.75 ppm	0.79 ppm	0.65 ppm	0.61 ppm

Subsequently, performance testing of the PCO air purifier was conducted. Following the activation of the PCO air purifier, Fig. 7 clearly illustrates a reduction in TVOC concentration at all measurement locations. Indicate that the AP PCO can reduce cigarette smoke pollutants to concentrations close to or even below the initial condition of the room without pollutants.

Fig. 7 illustrates the spatial distribution of TVOC concentrations recorded at five different measurement points (four corners and the center) throughout the degradation process. As observed in the graph, there are noticeable differences in the peak heights and decay rates at each angle.

These variations indicate that the dispersion of cigarette smoke within the 136 m³ room was not immediately uniform. The points showing higher concentration peaks likely correspond to areas with limited airflow or stagnant zones, where pollutants accumulated before being drawn into the purification system. Conversely, measurement points closer to the airflow path of the device exhibited lower peak concentrations and faster decay rates. This phenomenon highlights the influence of airflow dynamics on purification efficiency; while the PCO system effectively reduces the overall load, the local degradation rate is dependent on how effectively the air circulates from the room's corners to the reactor unit.

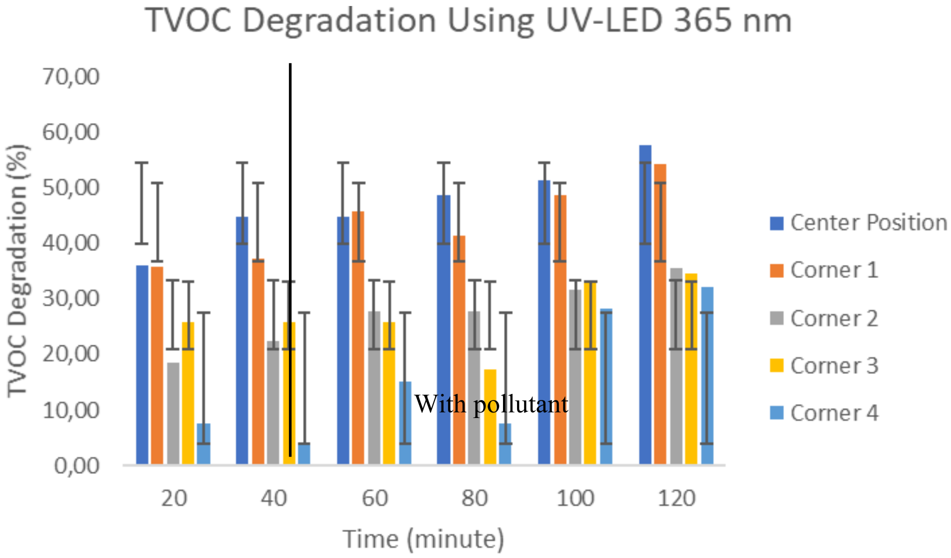

Fig. 7. Measurement results of TVOC degradation using UV-LED 365 nm.

Table 3 shows that the highest decrease in TVOC concentration occurred at the center position, from 0.78 ppm to 0.33 ppm over 2 hours, based on the calculation using Eq (1). This resulted in a reduction percentage was 57.69%. Equipped with a TiO_2-coated SS mesh reactor and a 365 nm UV-LED, it reduced VOC levels in the room. This is by the theory; titanium oxide is activated by photons with an energy greater than the band gap (about 360 nm) [27].

Table 3. Measurement results of TVOC concentration using UV-LED 365 nm

Minute	Center position	Corner 1	Corner 2	Corner 3	Corner 4
20	0.5 ppm	0.45 ppm	0.62 ppm	0.43 ppm	0.49 ppm
40	0.43 ppm	0.44 ppm	0.59 ppm	0.43 ppm	0.51 ppm
60	0.43 ppm	0.38 ppm	0.55 ppm	0.43 ppm	0.45 ppm
80	0.4 ppm	0.41 ppm	0.55 ppm	0.48 ppm	0.49 ppm
100	0.38 ppm	0.36 ppm	0.52 ppm	0.39 ppm	0.38 ppm
120	0.33 ppm	0.32 ppm	0.49 ppm	0.38 ppm	0.36 ppm

Activation of TiO_2 by UV light can be written as Eq. (2).

$$TiO_2 + hv \rightarrow h^+ + e- \quad (2)$$

In this reaction, holes (h^+) act as strong oxidizing agents, while free electrons (e-) act as strong reducing agents. These oxidation and reduction reactions are explained as Eq. (3) and Eq. (4), respectively.

$$OH^- + h^+ \rightarrow OH \quad (3)$$

$$O_{2\ ads} + e^- \rightarrow O^{-2}{}_{ads} \quad (4)$$

When organic compounds undergo degradation, hydroxyl radicals (OH*) are formed from water oxidation or OH^- ions attached to the surface, acting as the main oxidizing agent. In addition, oxygen in the reaction environment helps prevent electron and hole pairs from recombining. If the oxidation photocatalysis reaction is complete, the result is Carbon Dioxide (CO_2) and water (H_2O) [27] (Eq. 5). The products can be in form of CO_2 or H_2O.

$$OH^* + \text{pollutant} + O_2 \rightarrow \text{products} \quad (5)$$

3.2 Results of cigarette smoke pollutant reduction using 390 nm UV-LED

An experiment was conducted to evaluate photocatalytic performance by replacing the UV-LED. A 390 nm UV-LED was used because the TiO_2 photocatalyst can also be activated at this wavelength.

As in the previous test phase, a reduction in TVOC concentration was observed at all measurement points when the PCO reactor was activated. Fig. 8 clearly illustrates a reduction in TVOC concentration at all measurement locations. As shown in Table 4, the highest concentration drop occurred from 0.86 ppm to 0.32 ppm at the center position, resulting in a degradation rate of 62.8% within 2 hours, as calculated using Eq. (1).

Although there was a difference in light wavelength, the results indicate that photocatalytic performance is not significantly affected if the wavelength remains within the range capable of activating TiO_2. The intensity of the UV light is also an influential factor in the effectiveness of the degradation process [28] and the initial concentration level of pollutants in the room [29].

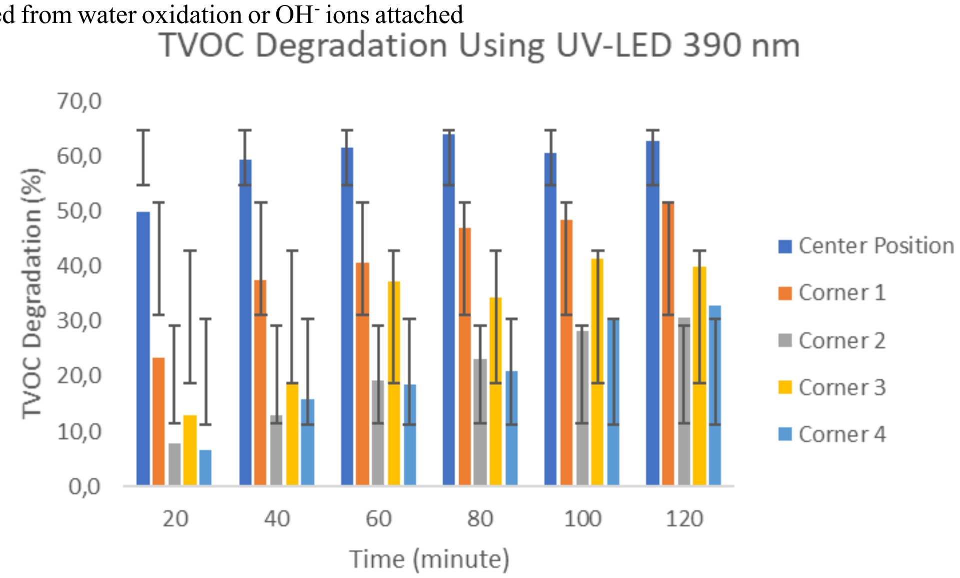

Fig. 8. Measurement results of TVOC degradation using UV-LED 390 nm.

Table 4. Measurement results of TVOC concentration using UV-LED 390 nm

Minute	Center position	Corner 1	Corner 2	Corner 3	Corner 4
20	0.43 ppm	0.49 ppm	0.72 ppm	0.61 ppm	0.71 ppm
40	0.35 ppm	0.4 ppm	0.68 ppm	0.57 ppm	0.64 ppm
60	0.33 ppm	0.38 ppm	0.63 ppm	0.44 ppm	0.62 ppm
80	0.31 ppm	0.34 ppm	0.6 ppm	0.46 ppm	0.6 ppm
100	0.34 ppm	0.33 ppm	0.56 ppm	0.41 ppm	0.53 ppm
120	0.32 ppm	0.31 ppm	0.54 ppm	0.42 ppm	0.51 ppm

4 Conclusions

Based on the results of the research conducted, it can be concluded that the use of a stainless-steel mesh reactor coated with TiO_2 has proven to be highly effective as the main component in a Photocatalytic Oxidation (PCO)-based air purification system. Combining this reactor with a UV-LED light source at wavelengths of both 365 nm and 390 nm successfully reduced concentrations of airborne pollutants in the form of Total Volatile Organic Compounds (TVOC).

In the test using a 365 nm UV-LED, the highest reduction in TVOC concentration was observed from 0.78 ppm to 0.33 ppm, resulting in a degradation rate of 57.69% over two hours. Meanwhile, in the test using a 390 nm UV-LED, the degradation rate increased to 62.8%, with a concentration drop from 0.86 ppm to 0.32 ppm. This performance is supported by the characteristics of the stainless-steel mesh, which offers high durability and an optimal surface area for facilitating photocatalytic processes.

Activation of TiO_2 by UV light generates hydroxyl radicals (OH*), which play a key role in breaking organic compounds into safer substances such as carbon dioxide and water. Although there were variations in the UV-LED wavelength, these differences did not significantly impact photocatalytic performance. Instead, the effectiveness of the process was more influenced by the intensity of the UV light and the initial concentration of pollutants.

Therefore, the PCO system utilizing a TiO_2-coated stainless steel mesh reactor and UV-LED light source can serve as an effective and environmentally friendly solution for improving indoor air quality, particularly in reducing the impact of cigarette smoke pollution.

References

[1] W. I. D. Aurora, "Efek Indoor Air Pollution Terhadap Kesehatan," *e-SEHAD*, vol. 1, no. 2, pp. 32–39, 2021.

[2] N. E. Klepeis *et al.*, "The National Human Activity Pattern Survey (NHAPS): a resource for assessing exposure to environmental pollutants," 2001. [Online]. Available: www.nature.com/jea

[3] J. Rovira, N. Roig, M. Nadal, and J. L. Domingo, "Human health risks of formaldehyde indoor levels: An issue of concern."

[4] S. Zhang, H. Chen, J. Zhang, J. Li, H. Hou, and Q. Hu, "The multiplex interactions and molecular mechanism on genotoxicity induced by formaldehyde and acrolein mixtures on human bronchial epithelial BEAS-2B cells," *Environ Int*, vol. 143, Oct. 2020, doi: 10.1016/j.envint.2020.105943.

[5] X. Wang, "Tobacco," *Elsevier eBooks*, pp. 77–86, Jan. 2023.

[6] D. B. Barr, P. Panuwet, and P. B. Ryan, "Volatile Organic Chemicals," *Oxford University Press*, pp. 515–529, Apr. 2024.

[7] A. L. Morgan, F. R. Torpy, P. J. Irga, R. Fleck, R. L. Gill, and T. Pettit, "The botanical biofiltration of volatile organic compounds and particulate matter derived from cigarette smoke," *Chemosphere*, vol. 295, May 2022.

[8] Ioannis and George, "REMOVAL OF NOXIOUS OXIDANTS AND CARCINOGENIC VOLATILE NITROSOCOMPOUNDS FROM CIGARETTE SMOKE USING BIOLOGICAL SUBSTANCES," Jan. 04, 1996

[9] B. H. Permana, P. Thiravetyan, and C. Treesubsuntorn, "Effect of airflow pattern and distance on removal of particulate matters and volatile organic compounds from cigarette smoke using Sansevieria trifasciata botanical biofilter ," *Chemosphere* , vol. 295, no. 4, Feb. 2022.

[10] A. H. Mamaghani, F. Haghighat, and C. S. Lee, "Photocatalytic oxidation technology for indoor environment air purification: The state-of-the-art," *Appl Catal B*, vol. 203, pp. 247–269, 2017, doi: 10.1016/j.apcatb.2016.10.037.

[11] A. A. Bakheet, M. F. Mohd Zain, A. A. Kadhum, and Z. Abdalla, "Photocatalytic Oxidation Performance to Removal of Volatile Organic Compounds in Indoor Environment," *Environmental Research, Engineering and Management*, vol. 58, no. 4, Dec. 2011, doi: 10.5755/j01.erem.58.4.308.

[12] H. Slimen, T. Ochiai, and K. Nakata, "Photocatalytic Decomposition of Cigarette Smoke Using a TiO2-Impregnated Titanium Mesh Filter," *ACS Publications* , Dec. 2011.

[13] P. Chanklom, T. Kreetachat, R. Chotigawin, and K. Suwannahong, "Photocatalytic Oxidation of PLA/TiO2-Composite Films for Indoor Air Purification," *ACS Omega*, vol. 6, no. 16, pp. 10629–10636, Apr. 2021, doi: 10.1021/acsomega.0c06194.

[14] P. M. Adhi, H. Rahman, I. Nuriskasari, Syamsudin, and A. Syahrom, "A Simple and Low-cost Photocatalytic Air Purification Test Method," in *Journal of Physics: Conference Series*, Institute of Physics, 2022. doi: 10.1088/1742-6596/2243/1/012075.

[15] L. Xu, J. Chen, P. Zhao, B. Shen, Z. Zhou, and Z. Wang, "Stable Loading of TiO2 Catalysts on the Surface of Metal Substrate for Enhanced Photocatalytic Toluene Oxidation," *Molecules*, vol. 28, no. 17, Sep. 2023, doi: 10.3390/molecules28176187.

[16] W. Wang, S. Zhao, X. Wang, C. Chen, and H. Yi, "Stainless steel catalyst for air pollution control: structure, properties, and activity," *Environmental Science and Pollution Research*, vol. 29, no. 37, Jun. 2022.

[17] J. Sico *et al.*, "Fabrication and Characterization of TiO2 Coatings on 304 Stainless-Steel Substrate for Efficient Oil/Water Separation," *Coatings*, vol. 13, no. 11, Nov. 2023, doi: 10.3390/coatings13111920.

[18] W. Scholarship, J. M. Garcia Hernandez, S. Hugo de Lasa, and G. Hernandez, "Photocatalytic Reactors for Air Treatment: Energy Efficiencies and Photocatalytic Reactors for Air Treatment: Energy Efficiencies and Kinetic Modeling Kinetic Modeling Recommended Citation Recommended Citation," Apr. 2012. [Online]. Available: https://ir.lib.uwo.ca/etd

[19] M. A. Camacho-González *et al.*, "High Photocatalytic Efficiency of Al2O3-TiO2 Coatings on 304 Stainless Steel for Methylene Blue and Wastewater Degradation," *Catalysts*, vol. 13, no. 10, Oct. 2023, doi: 10.3390/catal13101351.

[20] R. W. Melse and M. A. Hilhorst, "Photocatalytic oxidation on TiO2 of methane from exhaust air of animal houses and liquid manure storages," Dec. 2003. [Online]. Available: https://www.researchgate.net/publication/40796150

[21] H. Chen, C. E. Nanayakkara, and V. H. Grassian, "Titanium dioxide photocatalysis in atmospheric chemistry," *Chem Rev*, vol. 112, no. 11, pp. 5919–5948, 2012, doi: 10.1021/cr3002092.

[22] J. Mo, Y. Zhang, Q. Xu, J. J. Lamson, and R. Zhao, "Photocatalytic purification of volatile organic compounds in indoor air: A literature review," May 2009. doi: 10.1016/j.atmosenv.2009.01.034.

[23] "DATASHEET ML8511," Aug. 2013.

[24] AHAM, "Method for Measuring Performance of Portable Household Electric Room Air Cleaners," 2013.

[25] C. yong Li, Y. rong Jia, X. chao Zhang, S. ying Zhang, and A. dong Tang, "Photocatalytic degradation of formaldehyde using mesoporous TiO2 prepared by evaporation-induced self-

assembly," *J Cent South Univ*, vol. 21, no. 11, pp. 4066–4070, Nov. 2014, doi: 10.1007/s11771-014-2398-1.

[26] Y. Huang *et al.*, "Removal of indoor volatile organic compounds via photocatalytic oxidation: A short review and prospect," *Molecules*, vol. 21, no. 1, 2016, doi: 10.3390/molecules21010056.

[27] J. Zhao and X. Yang, "Photocatalytic oxidation for indoor air purification: A literature review," *Build Environ*, vol. 38, no. 5, pp. 645–654, 2003, doi: 10.1016/S0360-1323(02)00212-3.

[28] X. G. Qu, W. X. Liu, J. Ma, and W. Cao, "Research on photodegradation of formaldehyde by nanocrystalline N-TiO 2 powders under visible light irradiation," in *Research on Chemical Intermediates*, Mar. 2009, pp. 313–320. doi: 10.1007/s11164-009-0026-8.

[29] Y. T. Wu *et al.*, "Enhanced xylene removal by photocatalytic oxidation using fiber-illuminated honeycomb reactor at ppb level," *J Hazard Mater*, vol. 262, pp. 717–725, Nov. 2013, doi: 10.1016/j.jhazmat.2013.09.037.