Air Pollutant Detection System Utilizing an IoT-based Electronic Nose for Air Purifier

2022 6th International Conference on Electrical, Telecommunication and Computer Engineering (ELTICOM) | 979-8-3503-2071-8/22/$31.00 ©2022 IEEE | DOI: 10.1109/ELTICOM57747.2022.10037913

Jessie Jay R. Balbin
School of EECE
Mapua University
Manila, Philippines
jjrbalbin@mymail.mapua.edu.ph

Aaron Jemiel G. De Guzman
School of EECE
Mapua University
Manila, Philippines
ajdeguzman@mymail.mapua.edu.ph

Christian Jhopete C. Rambuyon
School of EECE
Mapua University
Manila, Philippines
cjcrambuyon@mapua.edu.ph

Abstract*—Air pollution is a substance that is present in the atmosphere that may cause a possible threat to human health. It can come from vehicles, factories, dust, volcanoes, mold spores, and wildfire. The most common pollutants in the air are Ozone, particulate matter, Carbon monoxide (CO), Nitrogen dioxide (NO2), and Sulfur Dioxide (SO2). This study developed an electronic nose that detects CO and PM2.5, and PM10, and it is integrated with the air purifier to purify the air pollutants present in the air. The Arduino Uno is the microprocessor for creating the electronic nose, and the MQ-7 gas sensor detects carbon monoxide. The particulate matter was detected using a PMS5003 sensor. An application developed using the MIT app inventor for the graph and numerical values of the air pollutants to be able to see it in real-time. The testing area device is in the different household parts: the kitchen, dining room, living room, and bedroom. There were ten trials; the trials were per minute. The results recorded before and after air purification concluded a significant decrease in air pollutants after the air purification. Verified the results by using a paired t-test statistical treatment.

***Keywords*—Air pollution, Arduino Uno, MQ-7, PMS5003, Paired t-test**

I. INTRODUCTION

In the environment, air pollution is present, which are substances that can put human health at risk. The sample of air pollutants that are common in causing air pollution in the atmosphere is Ozone(O3), particulate matters such as PM1, PM2.5, and PM10, Carbon monoxide (CO), Nitrogen dioxide (NO2), and Sulfur Dioxide (SO2). Air pollutants are byproducts from factories, machines, vehicles, fuel burning, materials, dust, volcanoes, wildfire, and molds [1]. The Philippines is known for its air pollution problem, ranked 3rd in the most deaths due to outdoor air pollution in ASIA. With a reported death of 45.3 deaths every hundred thousand people. The Philippines is also reported as the 2nd with the most deaths due to indoor air pollution in 2018. According to Toma Cruz, nine individuals breathe unhealthy air every ten individuals [2]. Air pollution poses a significant health threat to people if exposed to air pollutants daily for a long time because it can increase the risk of diseases and inflammatory infections in the lungs. Also, it can amplify the infection rate of diseases, especially the COVID-19 virus in this pandemic. There is a higher chance of getting infected by COVID-19 if a human has a low immune system, in which air pollutants lower the immune system, which can lead to infection of COVID-19 [3]. Inhaling air pollutants can lead to diseases like cardiovascular disease, skin diseases, cancer if exposed to a high level of pollution, irritation in the body, stroke, and heart diseases [4]. Indoor pollution is happening daily in the whole world. According to WHO, there are 3.8 million deaths due to indoor pollution in households [5].

The intelligent air purifier that can recognize the variables mentioned in the sensors and the particles filtered by the air purifier system was developed in the paper by Idziak et al. using humidity, pressure, dust, and temperature sensors [6]. The project resulted in the efficiency and purification of the air pollutants detected in the place. It is an upgraded air purifier because it makes the air purifier smart. Also, Yang conducted a study where researchers created a Wi-Fi-based indoor air quality monitoring system. Researchers used temperature, humidity, and particulate matter sensors [7]. The usage of WIFI helps them to get better date visuals of the air purifying system. In Maiga's study, researchers developed a wardrobe air purifying system using temperature, dust, and humidity sensor. This device helps the wardrobe to be mold free and lessens the concentration of dust, not to damage the quality of clothes [8]. Lastly, the study by Rodriguez was an air purifying system created using a HEPA filter simultaneously as a plant monitoring system. Researchers have used particulate matter, moisture, nitrogen dioxide, and ammonia sensors. Researchers have created an air purifying system inside the pot of the plant while at the same time checking the plant's moisture as well [9].

In order to improve the air quality in households, this paper has included particulate matter ten as well as a carbon monoxide sensor to detect more air pollutants in the household and aim to purify the pollutants that are present in the place. The previous study focused on particulate matter 2.5. Carbon Monoxide is also considered a harmful pollutant to human health. Inhaling this substance in high amounts can lead to respiratory problems over time as well as diseases. It will also benefit a smoker inside the household because smoking produces much particulate matter and carbon monoxide. Also, the developed application is to monitor the levels of carbon monoxide and particulate matter (2.5 and 10) if it is safe.

The main objective of this study is to detect and capture air pollutants in households using an IoT-based electronic nose for air purifiers. The specific objectives of this study are (1) to develop a device that detects air pollutants, specifically carbon monoxide (CO) and particulate matter PM2.5 and PM10, using an IoT-based electronic nose and monitoring system. (2) to capture such air pollutants, mainly carbon monoxide and particulate matter PM2.5 and PM10 (3) to create a graphical user interface (GUI) for monitoring the air obtained by the gas sensor and PM sensor. (4) to test the IoT-based electronic nose in different parts of a Household in Metro Manila.

979-8-3503-2071-8/22/$31.00 ©2022 IEEE

The proposed system will benefit the people who use it in the household. It is because it will have much safer air for breathing and can monitor the air quality in the household. The proposed system will reduce the risk of respiratory diseases inclined to air pollutants. Carbon monoxide and particulate matter can weaken a person's overall health; thus, this system will help to reduce the risk of having this kind of problem. This device can reduce the concentration of carbon monoxide and particulate matter inside the household. It can improve the air quality in households.

The study is limited to detecting carbon monoxide (CO) and PM2.5, and PM10. In the different parts of a household. Also, it only focuses on reducing the concentration of CO and PM10, and PM2.5. The device set a threshold of 10 parts per million for CO, 25 micrograms per cubic meter for PM10, as well as 10 micrograms per cubic meter for PM2.5.

II. Methodology

This chapter will provide a brief overview of how the system will be utilized to monitor specific air pollutants and begin air purification. The approach covers the framework and architecture utilized in the study.

A. Conceptual Framework

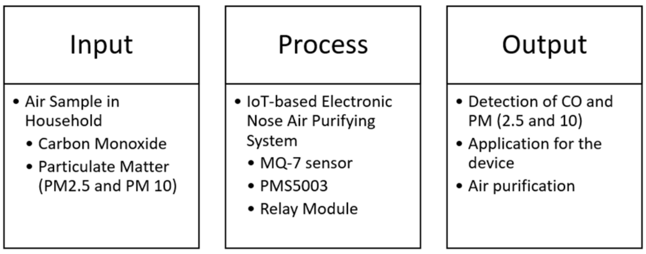

Fig. 1. Conceptual Framework of the Study

Fig. 1 shows the conceptual framework of the device. The parameters needed for the air pollutant detection were PM2.5 and PM10, as well as carbon monoxide. The MQ-7 and the PMS5003 sensor will detect and analyze the concentrations of the specified air pollutants. Suppose said pollutants are detected above the threshold. In that case, the Arduino will automatically turn on the air purifier, initiating air purification. The GUI mobile application will also display data from the gas sensors gathered by the Arduino. The application will continue to receive readings from the sensor before, during, and after air purification.

B. System Architecture

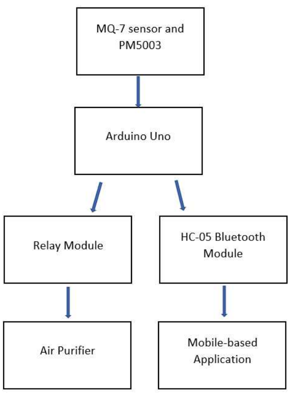

Fig. 2. Block Diagram of the Proposed Prototype

Fig. 2, the system architecture of this study consists of the sensors, which are the MQ-7 sensor and PMS5003 sensor connected to the Arduino Uno, as well as the relay module and Bluetooth module. The relay module is connected to an air purifier to turn on when the sensors reach the threshold. The Bluetooth module is responsible for the app's connection and the electronic nose value readings. Carbon monoxide has a threshold of 10ppm, but the unhealthy level of CO is 25ppm; it is set to 10 ppm to prevent the risk before it happens. PM10 has a threshold of 25 µg/m3, and PM2.5 has a threshold of 10 µg/m3. The unhealthy level of PM 2.5 and PM10 are 12 µg/m3 and 80 µg/m3, respectively [10]. Arduino Uno was chosen by the researchers because this consist of i/o boards, which are necessary for the sensors, relay, and Bluetooth module. Also, it can accomplish by programming based on the codings on the board [11].

In fig. 2 shows the block diagram of the proposed prototype. It shows that the carbon monoxide and particulate matter sensor connects to the Arduino, the relay, and Bluetooth modules. The relay module is responsible for the on and off of the air purifier. In contrast, the Bluetooth module is responsible for connecting the electronic nose and the mobile application in the smartphone. The MQ-7 sensor is for the detection of carbon monoxide. Metal oxide semiconductor (MOS) sensors detect many types of gasses by detecting the resistance change in the metal oxide obtained from the absorption of the gas in the area. MQ-7 is sensitive to carbon monoxide [12]. The PMS5003 sensor is to detect particulate matter 2.5 and 10. The PMS5003 particulate matter sensor will be the sensor that detects the particulate matter in the surroundings. It uses the laser scattering principle to detect the particulate matter in the air [13]. The sensors connect to the Arduino Uno, and the HC-05 Bluetooth module is for Bluetooth connectivity between the electronic nose and the application.

III. Results and Discussion

The device is located in different household areas: the kitchen, bedroom, living room, and dining room. The kitchen has an area of 2 m x 4 m, the dining room has an area of 2.4 m x 2.8 m, the living room has an area of 3.6 m x 2.8 m, and the bedroom has an area of 3.6 m x 2.8 m. The PM10 threshold will be greater than 25(µg/m3); for PM2.5, the threshold is greater than 10(µg/m3).

A. Data Gathered

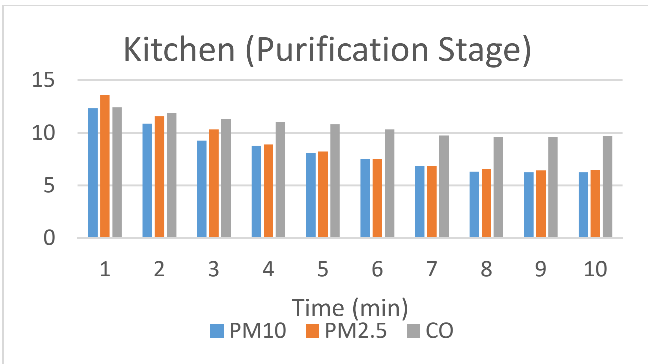

Fig. 3. Kitchen Area Values After Cooking (Purification Stage)

Fig. 3 shows the value in the first 10 minutes while the device was in the kitchen after cooking. The units of PM10 and PM2.5 are in $(\frac{\mu g}{m^3})$ for the unit of CO is in ppm. If the threshold is reached, the remarks will be dangerous, and if not, remarked as safe.

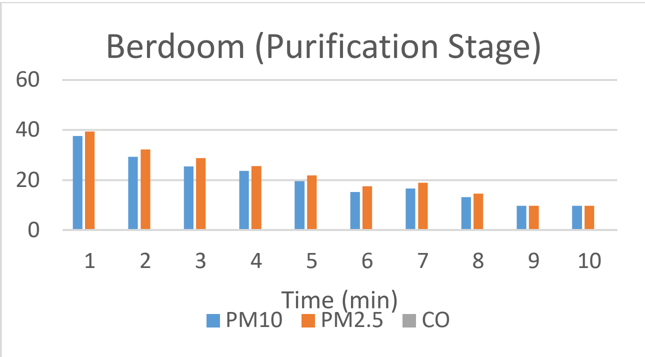

Fig. 4. Bedroom Area Values (Purification Stage)

Fig. 4 shows the value in the first 10 minutes while the device was in the bedroom. The units of PM10 and PM2.5 are in $(\frac{\mu g}{m^3})$ for the unit of CO is in ppm. The value of CO is not seen because it is almost having a 0 value. If the threshold is reached, the remarks will be dangerous, and if not, remarked as safe.

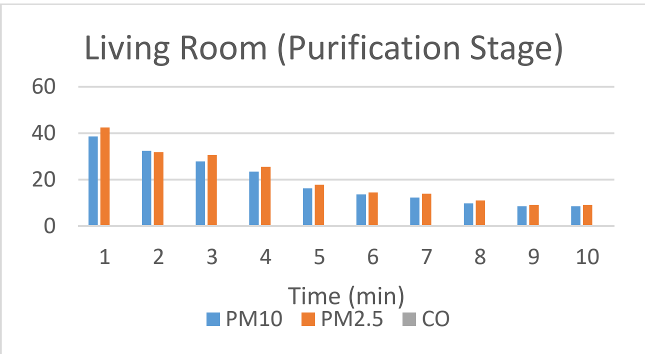

Fig. 5. Living Room Area Values (Purification Stage)

Fig. 5 shows the value in the first 10 minutes while the device was in the living room. The units of PM10 and PM2.5 are in $(\frac{\mu g}{m^3})$ for the unit of CO is in ppm. The value of CO is not seen because it is almost having a 0 value. If the threshold is reached, the remarks will be dangerous, and if not, remarked as safe.

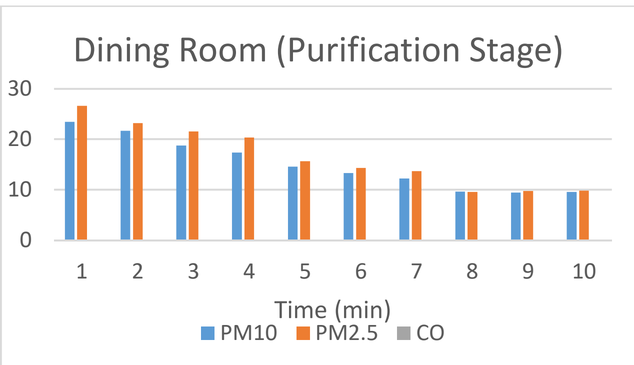

Fig. 6. Dining Room Area Values (Purification Stage)

Fig. 6 shows the value in the first 10 minutes while the device was in the dining room. The units of PM10 and PM2.5 are in $(\frac{\mu g}{m^3})$ for the unit of CO is in ppm. The value of CO is not seen because it is almost having a 0 value. If the threshold is reached, the remarks will be dangerous, and if not, remarked as safe.

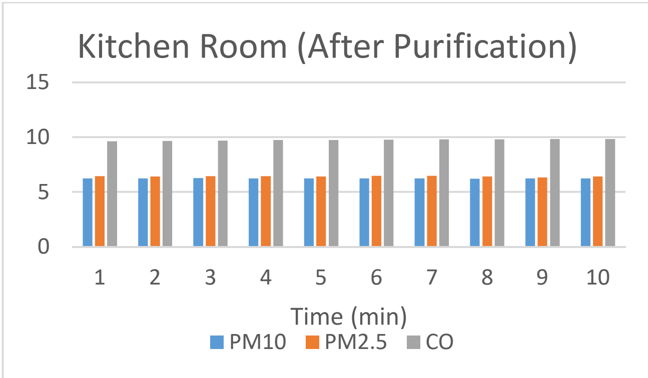

Fig. 7. Kitchen Room Area Values After Cooking (After Purification)

Fig. 7 shows the value in the first 10 minutes after the purification of the air in the kitchen. If the threshold is reached, the remarks will be dangerous, and if not, remarked as safe. In this reading, all the values are marked as safe.

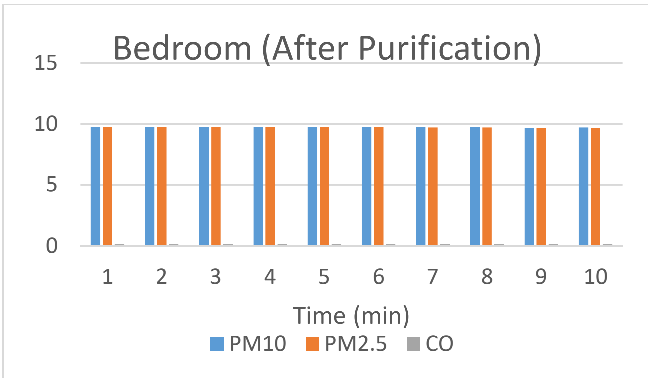

Fig. 8. Bedroom Area Values (After Purification)

Fig. 8 shows the value in the first 10 minutes after the purification of the air in the bedroom. If the threshold is reached, the remarks will be dangerous, and if not, remarked as safe. In this reading, all the values are marked as safe.

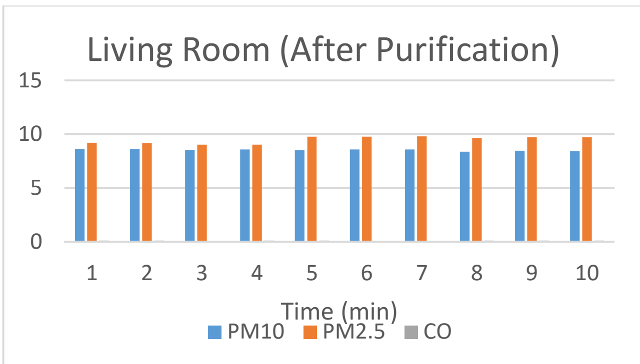

Fig. 9. Living Room Area Values (After Purification)

Fig. 9 shows the value in the first 10 minutes after the purification of the air in the living room. If the threshold is reached, the remarks will be dangerous, and if not, remarked as safe. In this reading, all the values are marked as safe.

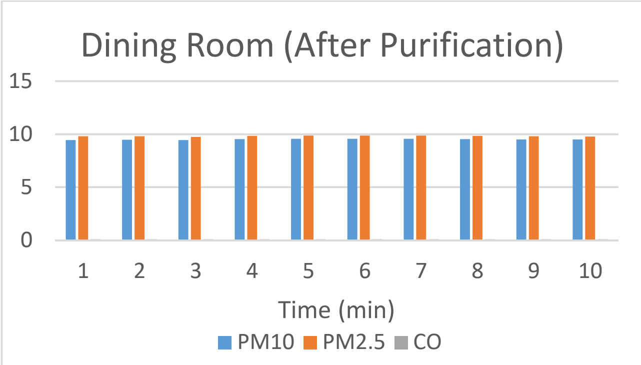

Fig. 10. Dining Room Area Values (After Purification)

Fig. 10 shows the value in the first 10 minutes after the purification of the air in the dining room. If the threshold is reached, the remarks will be dangerous, and if not, remarked as safe. In this reading, all the values are marked as safe.

B. *Statistical Treatment*

Testing the data gathered if there is a difference before and after the air purification, the paired T-test determines if there is a significant or no difference.

TABLE I. KITCHEN AREA PAIRED T-TEST STATISTICAL VALUES (CO)

	Statistical Values
∑D	8.94
∑D²	18.60
Average ∑D	0.89
SS_D	10.61
t statistic	2.60
t-critical value	2.26

Table 1 compares 10 minutes before air purification and 10 minutes after air purification values in the kitchen. The comparison of carbon monoxide concentration in the kitchen area is because it reaches dangerous remarks. Here we can conclude there is a difference in the data before and after because t-static > t-critical value; hence it rejects the null hypothesis. So it can be concluded that there is a significant decrease in carbon monoxide after air purification.

TABLE II. BEDROOM AREA PAIRED T-TES STATISTICAL VALUES (PM10 AND PM2.5)

	Statistical Values (PM10)	Statistical Values (PM2.5)
∑D	102.72	113.27
∑D²	1779.06	2082.15
Average ∑D	10.27	11.33
SS_D	723.92	799.14
t statistic	3.62	3.80
t-critical value	2.26	2.26

Table 2 compares 10 minutes before air purification and 10 minutes after air purification values in the bedroom. The comparisons of PM10 and PM2.5 density in the bedroom area are because it reaches the dangerous remarks. Here we can conclude that there is a difference in the data before and after because t-static > t-critical value; hence it rejects the null hypothesis for the conclusion that there is a significant decrease in PM10 and PM2.5 after air purification.

TABLE III. LIVING ROOM AREA PAIRED T-TES STATISTICAL VALUES (PM10 AND PM2.5)

	Statistical Values (PM10)	Statistical Values (PM2.5)
∑D	106.37	109.54
∑D²	2161.29	2289.12
Average ∑D	10.64	10.95
SS_D	1029.83	1089.22
t statistic	3.14	3.15
t-critical value	2.26	2.26

Table 3 shows the comparison of 10 minutes before air purification and 10 min after air purification values in the living room. The comparison of PM10 and PM2.5 density in the living room area is because it reaches dangerous remarks. Here we can conclude that there is a difference in the data before and after because t-static > t-critical value; hence it rejects the null hypothesis, so it can conclude that there is a significant decrease in PM10 and PM2.5 after air purification.

TABLE IV. THE DINING ROOM AREA PAIRED T-TES STATISTICAL VALUES (PM10 AND PM2.5)

	Statistical Values (PM10)	Statistical Values (PM2.5)
∑D	55.85	60.36
∑D²	540.24	655.52
Average ∑D	5.59	6.04
SS_D	228.32	291.19
t statistic	3.51	3.36
t-critical value	2.26	2.26

Table 4 compares 10 minutes before air purification and 10 minutes after air purification values in the dining room. The PM10 and PM2.5 density of the dining room is analyzed because it reaches dangerous remarks. Here it can conclude that there is a difference in the data before and after because t-static > t-critical value; hence it rejects the null hypothesis, so there is a significant decrease in PM10 and PM2.5 after air purification.

Fig. 11 shows the GUI of the application. It shows the gathered values of the sensors. If the threshold value is not reached, it will indicate a “safe” for the remarks, and if the threshold value is reached, it will indicate "dangerous" for the remarks. Also, it shows the graph of the sensor values below, as shown in fig. 11.

Fig. 12 shows the floor plan of the house. The living room has an area of 3.6m x 2.8m. The Dining room has an area of 2.4m x 2.8m. The bedroom has an area of 3.6m x 2.8m. The kitchen has an area of 2m x 4m. The device is placed as a circle with an x-mark, as seen in the figure. The pollutants come from natural sources for the living room, dining room, and bedroom. Monitorings were also conducted at noon when people outside the house were active. In the kitchen area, it was tested after cooking.

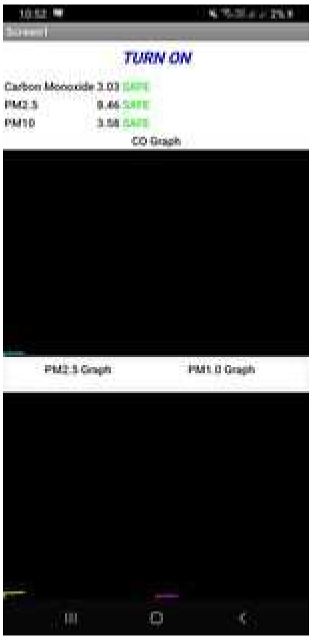

Fig. 11. Graphical User Interface of the Application

IV. Conclusion and Recommendation

The researchers have designed an electronic nose that was integrated into the air purifier to detect harmful pollutants in the air and simultaneously purify the pollutants. The researchers used the MQ7 sensor for detecting the carbon monoxide in the air, and the PMS5003 is responsible for detecting two types of particulate matter which are PM10 and PM2.5. MIT app inventor was used to create an application for the study to have a visual representation of the actual density and air pollutants concentration in air and the graph to see the decrease of concentration and density while the air is in the process of purification. The data was recorded every minute for ten (10) minutes in a before and after scenario.

Fig. 12. Resendential Floor Plan

The result of the data resulted in that it has a significant decrease in air pollutants in the air. All data have a t-critical value of 2.26. t-statistics data in the kitchen area for CO is 2.6; the t-statistics data in the bedroom area for PM10 and PM2.5 are 3.62 and 3.8, the t-statistics of data in the living room area for PM10 and PM2.5 are 3.14 and 3.15 respectively, and the t-statistics of the data in the dining room for PM10 and PM2.5 are 3.51 and 3.36 respectively. The t-statistics > t-critical value for the actual data indicates a significant decrease in air pollution in the different parts of the households.

The study is about purifying carbon monoxide and particulate matter in the air. Also, additional integrations of electronic sensors can with the air purifier are possible. The researchers recommend adding more air pollutants sensors if it is available in the market to check more air pollutants that are dangerous to people. Another recommendation is to make an easy plug for the electronic nose to connect to the air purifier for a much more flexible use of the electronic nose.

References

[1] NSW GOVERNMENT, "Air quality - Common air pollutants and their health effects," Common air pollutants and their health effects - Air quality, 29-Apr-2013. [Online]. Available: https://www.health.nsw.gov.au/environment/air/Pages/common-air-pollutants.aspx. [Accessed: 04-Apr-2021].

[2] S. Tomacruz, “Air pollution deaths 3rd highest in PH,” Rappler, 25-Jul-2018. [Online]. Available: https://www.rappler.com/nation/air-pollution-deaths-3rd-highest-philippines. [Accessed: 03-Apr-2021].

[3] M. Cole, C. Ozgen, and E. Strobl, “Air pollution exposure linked to higher COVID-19 cases and deaths – new study,” Interaksyon, 16-Jul-2020. [Online]. Available: https://interaksyon.philstar.com/politics-issues/2020/07/16/173055/air-pollution-exposure-linked-to-higher-covid-19-cases-and-deaths-new-study/. [Accessed: 04-Apr-2021].

[4] WHO. (2019, November 15). Health consequences of air pollution on populations. Retrieved April 11, 2021, from https://www.who.int/news/item/15-11-2019-what-are-health-consequences-of-air-pollution-on-populations

[5] WHO, “Household air pollution and health,” World Health Organization, 22-Sep-2021. [Online]. Available: https://www.who.int/news-room/fact-sheets/detail/household-air-pollution-and-health?fbclid=IwAR2ijfqeQ2ZalFL8TBn0iWRjIgtn2t-Z4TKMTzBzLMm3Z81iV3J-RkxYz-I. [Accessed: 22-Apr-2022].

[6] P. Idziak and M. Gojtowski, “Smart air purifier suitable for small public spaces,” ITM Web of Conferences, 2019. [Online]. Available: https://search.proquest.com/openview/ff570ca32670c9030a8d775895dcbc5d/1?pq-origsite=gscholar&cbl=2040552. [Accessed: 04-Apr-2021].

[7] X. Yang, L. Yang, and J. Zhang, "A WiFi-enabled indoor air quality monitoring and control system: The design and control experiments," 2017 13th IEEE International Conference on Control & Automation (ICCA), Ohrid, Macedonia, 2017, pp. 927-932, doi: 10.1109/ICCA.2017.8003185

[8] M. B. Marinov, D. I. Iliev, T. S. Djamiykov, I. V. Rachev, and K. K. Asparuhova, "Portable Air Purifier with Air Quality Monitoring Sensor," 2019 IEEE XXVIII International Scientific Conference Electronics (ET), Sozopol, Bulgaria, 2019, pp. 1-4, doi: 10.1109/ET.2019.8878570.

[9] M. G. A. Mapili, K. A. D. Rodriguez and J. T. Sese, "Smart Air Filtration System Using IoT and Kalman Filter Algorithm for Indoor Air Quality and Plant Monitoring," 2021 IEEE 11th International Conference on System Engineering and Technology (ICSET), 2021, pp. 309-314, doi: 10.1109/ICSET53708.2021.9612560.

[10] Center of Disease Control and Prevention. (2018, July 09). Carbon monoxide. Retrieved April 14, 2021, from https://www.cdc.gov/niosh/topics/co-comp/default.html

[11] Basset, “Department of Health,” Fine Particles (PM 2.5) Questions and Answers, Feb-2018. [Online]. Available: https://www.health.ny.gov/environmental/indoors/air/pmq_a.htm#:~:text=Exposure%20to%20fine%20particles%20can,as%20asthma%20and%20heart%20disease. [Accessed: 25-Apr-2022].

[12] A. Mainka, W. Mucha, J. S. Pastuszka, E. Brągoszewska, and A. Janoszek, “Non-commercial Air Purifier—The Effectiveness and Safety,” Buildings, vol. 10, no. 6, p. 104, 2020.

[13] Pickerng, P. and Twanow, C., 2021. Metal Oxide Gas Sensing Material and MEMS Process. [online] Fierce Electronics. Available at: https://www.fierceelectronics.com/components/metaloxidegassensingmaterialandmemsprocess#:~:text=MOS%20sensors%20detect%20concentration%20of,of%20the%20metal%20oxide%20material. [Accessed 18 April 2021].