INTEGRATED AIR QUALITY MANAGEMENT AND DISINFECTION SYSTEM TO MITIGATE COVID-19 IN CLASSROOMS

JUNE VERGEL P. QUEROL
International School of Asia and the Pacific
College of Information Technology and Engineering
Alimannao hills, Peñablanca, Cagayan
Email: jvquerol@isap.edu.ph

ABSTRACT: *Ensuring student safety and minimizing COVID-19 transmission are primary objectives for the International School of Asia and the Pacific (ISAP). This study presents an integrated IoT system, designed to enhance safety within the school's classrooms. Evidence highlights air pollution's role in exacerbating COVID-19 transmission, with classroom aerosols posing substantial risks (Domingo J. et al., 2020). Our system employs an MQ135 sensor, a disinfection machine, and an alcohol sensor to mitigate these risks. On detecting air quality deterioration beyond 100 ppm, the MQ135 sensor activates the air filter, while the mobile app sets a timer for the disinfection machine, ensuring regular sanitization cycles. The alcohol sensor relays usage data to the mobile app. This system strives for a safer environment through continuous monitoring and management of indoor air quality, disinfection schedules, and sanitizer usage, providing a compelling example of IoT technologies in public health.*

Keywords*: COVID-19 Transmission, Disinfection, Automation*

INTRODUCTION

COVID-19, an unexplained strain of pneumonia discovered in December 2019 in Wuhan, Hubei Province, China, has had a devastating impact on the global community. On March 12, 2020, the World Health Organization (WHO) declared the COVID-19 outbreak a pandemic. In response, traditional teaching methods were suspended across all levels of education, and online learning for undergraduate and graduate students became increasingly popular.Education is one of the industry's most severely affected by the COVID-19 pandemic. Due to the threat of the pandemic, many governments have chosen to temporarily close schools, affecting millions of children. Especially for younger students, the effects of the pandemic have caused academic setbacks.

President Duterte authorized limited face-to-face sessions in 120 public and private schools in low-risk areas for COVID-19 on September 20, 2021, according to Presidential Spokesman Harry Roque and Education Secretary Leonor Briones. This marked a policy shift towards resuming in-person education where it is safe to do so.

According to Domingo J. et al. (2020), as air pollution intensifies, so does the probability of COVID-19 transmission. Additional research by Fishman, L. (2021) indicates that COVID-19 can be transmitted through the air, particularly in confined spaces with insufficient ventilation. According to the Environmental Protection Agency of the United States (EPA 2021), although air purifiers can reduce airborne toxins, they are insufficient to protect against COVID-19. Air circulation, ventilation, and surface disinfection are crucial for preventing the spread of COVID-19.

In response to these obstacles, the researchers proposed a system for reducing the transmission of COVID-19 within the Engineering Laboratory. This system consists of disinfection machines, air purifiers, and alcohol level indicators for the purpose of aiding students, teachers, and staff in mitigating the COVID-19 pandemic and alleviating related concerns.

The figure below depicts the proposed system's system architecture.

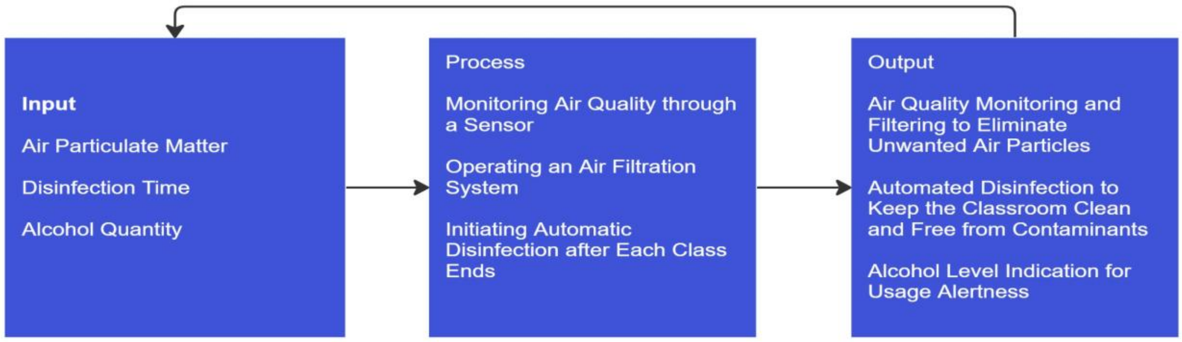


Figure1. System Framework

Figure 1 depicts how the system will operate. Inputs will include air particulate matter (PM) and disinfection time. An air monitoring system will detect particulate matter, air filtration and disinfection will be used to clean the air, and the alcohol concentration will be indicated. The final product will be an air quality monitoring system that filters and disinfects undesirable PM, disinfection for maintaining clean indoor surfaces, and alcohol level checks to ensure user alertness. To reduce COVID19 in the classroom effectively, the system will consist of three components: Monitoring of Air Filtration, Disinfection, and Sanitizer

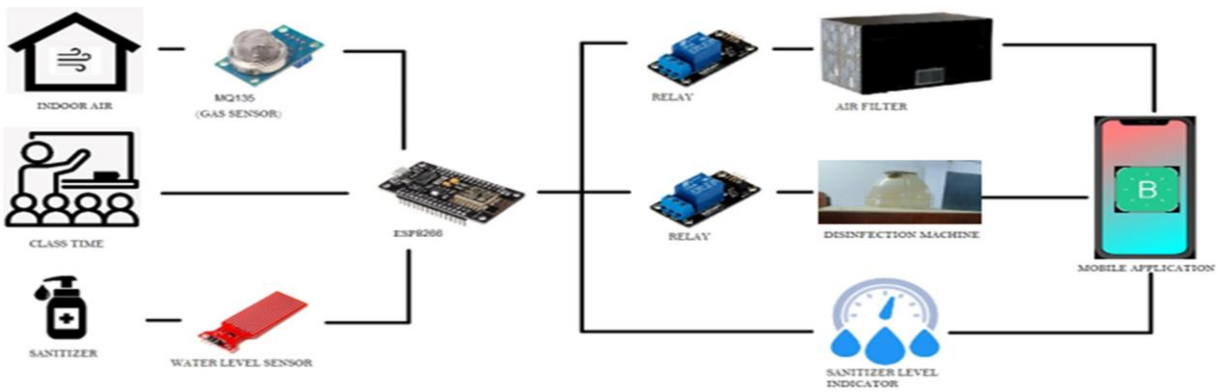


Figure2.Architecturaldesign

Figure 2 illustrates the system's Architectural Design. The ESP8266 will serve as the system's Internet connectivity medium. MQ135 gas sensor is used for air quality monitoring and as the trigger to activate the air filter; it can detect undesirable gases such as Ammonia, Nitrogen Oxide, Alcohol, Benzene, and Carbon-dioxide (CO_2), as well as undesirable particulate matter from PM2.5 to PM10. Real-Time clock (RTC) of the ESP8266 will be used to determine the automatic disinfection time. The sanitizer level indicator will employ a water level sensor. Lastly, a mobile application is used to monitor the overall air quality, disinfection time, and sanitizer level. This system filters the air, facilitates proper air circulation, cleans surfaces, and utilizes the correct quantity of sanitizer in preparation for the school's limited in-person classes.

PURPOSE OF THE STUDY

The purpose of the study is to devise a method for determining and achieving the following goals: 1) Create an architectural design for classroom air quality monitoring and CoVid-19 mitigating measures, 2) Create a system in preparation for limited face-to-face classes that are safer. 3) Define the technology to be developed for air filtration, surface disinfection, and alcohol level monitoring and 3) To evaluate the effectiveness of the air purification system.

This study focuses primarily on the system's design, which will be implemented exclusively in the Engineering Laboratory at MCNP-ISAP. The monitoring of this project will also involve Internet connectivity and a mobile application. Internet connectivity and power outages will subsequently become additional limitations of this system.

METHODOLOGY

The investigation utilized a descriptive development methodology. The researcher selected this research design to develop a prototype that will maintain proper air circulation, clean indoor air and surfaces, and observe proper quantity usage of alcohol sanitizer in mitigating air transmission of CoVid-19 for the preparation of limited face-to-face classes in one of the classrooms of International School of Asia and the Pacific, with the overall functionality of the system to be monitored via mobile application.

This study focuses on mitigating CoVid – 19 air transmissions and maintaining clean air and surfaces for a safer environment in preparation for limited face-to-face classes. The technology includes a system for air filtration, automatic disinfection, and alcohol level monitoring in pursuit of the researcher's objective. The objective of the system in the midst of the pandemic is to maintain a safe environment for students attending the limited face-to-face classes.

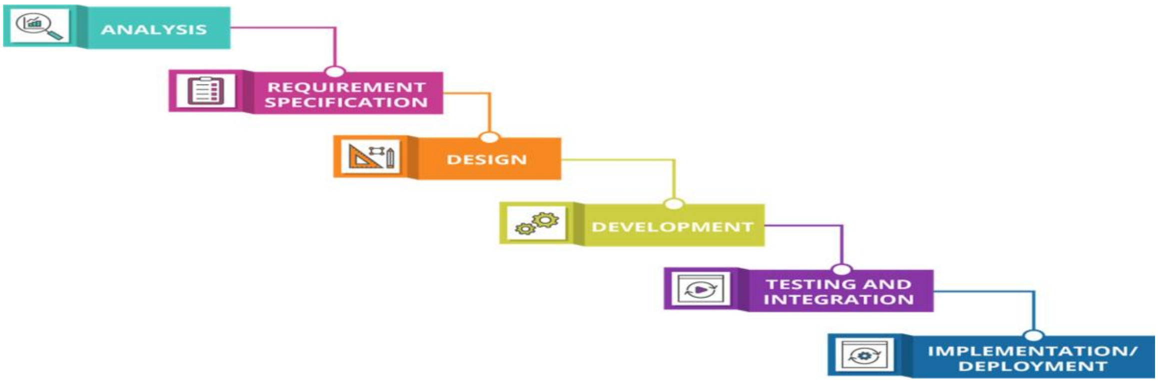


Figure 3 (left side figure) depicts the Waterfall Development Methodology that the researcher will employ to accomplish the study's objectives.

The Waterfall Model, also known as the Cascade method, is a synchronous method of software development in which the phases of a project flow smoothly from beginning to end. This involves documenting the entire project in advance, including the user interface, user stories, and all possible outcomes and permutations of the features. As the adage goes, the objective of the Waterfall method is to "measure twice, cut once" (Mars Discovery District, 2019).

Project Development Phases

First Phase: ANALYSIS. The first step is to conduct research in order to determine the most appropriate project to propose. The proposal is submitted and defended after receiving the project information. The proposal details the development's history, negative area, objectives, and requirements. This is the most crucial step in phase planning.During the course of the study, the researcher developed a method that can assist in providing a solution to the problems that individuals encountered during the pandemic, a system that can indicate and maintain the quality of air using an air purifier, a disinfecting machine to have clean air and surfaces, and a method for monitoring the amount of alcohol in an alcohol dispenser.

Second Phase: REQUIREMENTS. The initial step is to assess the requirements and fully comprehend the system's flaws. This is the research phase, with no construction taking place. The**.** The researcher makes a concerted effort to ask every question and collect every piece of information required to construct the product requirement. This is the most important component of phase planning.

Components	Description
BlynkApplication	Thisprogramwillbeusedtolinkthesystemtothecloudsothatamobileapplicationmay bedeveloped.
MobileApplication	Thissoftwareapplication(BlynkApplication) is used for the overallmonitoring of the system; the airquality,disinfectiontime,andsanitizerlevel.
MQ135gassensor	Itisalow-costgassensorforairqualitydetectionandservesasthetriggerforairfiltertofunction.
RealTimeClock	ItisthefunctionintheESP8266forreal-timemonitoringofautomaticdisinfection.
WaterLevelsensor	Asensor levels. used to monitor sanitizer

Third Phase: DESIGN. The researcher creates a system that filters airborne particles, measures the amount of alcohol in the dispenser, and monitors the disinfection time. Following is the system architecture that will be utilized to develop the project. The system architecture depicts the system's flow, operation, and the interconnections between the various components used by the project's developers.The researcher devises this plan in order to produce a disinfectant machine, an air purifier that filters the air quality, and a device to monitor the amount of alcohol in an alcohol dispenser.After final execution is completed, the product must be validated prior to beingdelivered to clients. Utilizing the product manager's design documents, personas, and user case scenarios, the researcher will develop test cases.

Fourth Phase: DEVELOPMENT. During this phase, the researcher will develop the project and test its overall functionality thoroughly.The researcher evaluates the air quality sensor by collecting data from a mobile application every minute for ten minutes per object, five minutes with and five minutes without an air filtration system. To test the sensor with and without an air filtration system, the researcher burned three objects.A t-test was used to determine the significance of the difference between the deployed air filtering system and the control group in order to evaluate the system's effectiveness.

Fifth Phase: TESTING. In this phase, the system will undergo its final testing, and the Waterfall methodology's projections will result in a predictable project release date. For example, you may discover additional information about a feature and need to modify the requirements. These variables will influence the project's delivery schedule and risk.

Sixth Phase: IMPLEMENTATION/DEPLOYMENT. The system will be implemented or deployed in the Engineering Laboratory of International School of Asia and the Pacific and presented to CpE Instructors and other ISAP faculty after the deployment project's final testing is complete.
As a foundation for redesigning the project, suggestions and recommendations will be provided.

RESULTS AND DISCUSSION

Figure 4 delineates all of the stipulated components for the invention of this project.

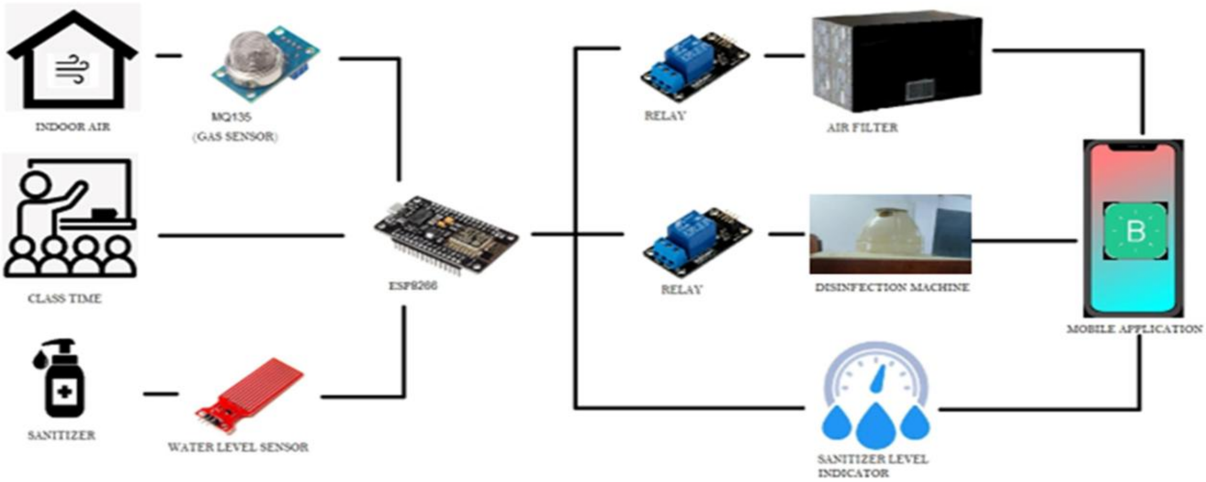


Figure4:Architecturaldesignoftheproject

The microcontroller will facilitate Internet connectivity for the system, while the Gas sensor will be used for air quality monitoring and to activate the air filter. The microcontroller's Real-Time Clock (RTC) will be used to determine the automatic disinfection time. The amount of water will be monitored using a sensor for the sanitizer level indicator. The system will utilize a mobile application to monitor the global air quality, disinfection time, and sanitizer concentration. This prepares the school to conduct a limited number of face-to-face classes by filtering the air, facilitating proper air circulation, cleaning surfaces, and applying the correct amount of sanitizer.

The researcher created a technological concept and a method for mitigating CoVid – 19 air transmissions in anticipation of the limited face-to-face classes. To explicitly ensure the health of each individual, the device will require an internet connection or mobile data and will notify the mobile application to disinfect and filter the air in the classroom before and after class. This section discusses the technology's design, as illustrated in Figures 6, 7, and 8.

TABLE2.CONTINUITYPLANOFTHESYSTEM

Air Filtration System	Changing the filter on a regular basis
Disinfection Machine	Provide disinfectant solution when the container is empty

The system's continuity plan, which is depicted in Table 2, outlines the actions that must be taken to maintain the system's functionality through human intervention.

The process of the system is depicted in figure 5's flowchart for the system.

If the ppm (parts per million) range of air particle quality assessment is 100 or greater, the air filtration system will automatically activate.If the sanitizer level range is less than or equal to 20 ml, the notification will activate automatically for the alcohol level in the alcohol stand.The time for the disinfection machine will be set by the user, preferably at the end of each day or after each class.This system filters the air, promotes proper air circulation, cleans surfaces, and utilizes the appropriate amount of sanitizer in preparation for the school's limited face-to-face classes.

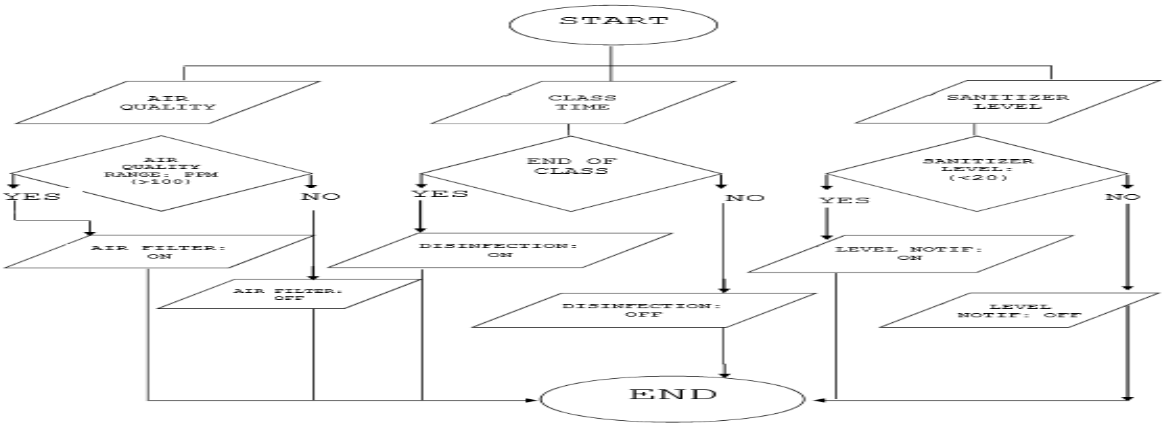
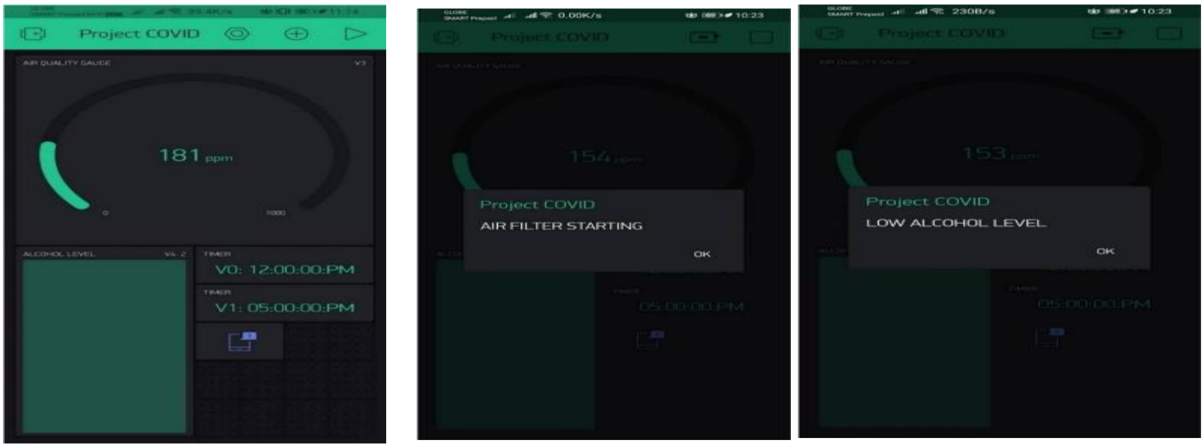


Figure 5: The flowchart of the system



In figure 6,(figure at the left) the mobile application layout of the system for air quality monitoring is illustrated.

Thefollowingarethefunctionsoftheapplication.

- The mobile application sends notifications when the air filter activates, which occurs when the particulate matter (PPM) present in the air exceeds 100.
- The application displays real-time levels of alcohol level in the dispenser and updates this information frequently.
- The application provides the start time of the disinfection machine, and it allows users to control the input parameters and operation time for the disinfection process.
-

DisinfectionMachine

Main Box/Alcohol LevelIndicator

AirFiltrationSystem

Figure7.Thedevices

Figure 7 presents images of the actual devices used in the system. Each component/device has its unique functionality, described as follows:Alcohol Level Indicator, this device monitors the quantity of alcohol present in the Alcohol dispenser.Main Box, the main box houses the system's primary microcontroller.Relays within the main box allow the air filtration system and disinfection machine to operate alternately.Disinfection Machine, the machine automatically initiates disinfection at the times set via the mobile application.The optimal operation times are during lunch break and afternoon dismissal, with a recommended run-time of 15-30 minutes to ensure complete classroom coverage.This process ensures the surfaces within the room are clean.

Air Filtration, the system uses an MQ135 sensor to detect and monitor air quality, with readings accessible via the mobile application. It purifies the air circulating within the room.The unit incorporates a UV LED light to clean the filter, supporting its long-term viability.Through their investigation into designing mitigation strategies for COVID-19 air transmission in preparation for limited face-to-face classes, the researcherhas developed a system that employs a mobile application for comprehensive monitoring of air quality, disinfection timing, and sanitizer levels.

Table 3 compares three system functionality variables with and without the air purifier, based on data collected during system testing. The results indicate that the installation of an air purifier significantly reduces the number of airborne particles.

Table 3: Comparison on the Functionality of the System to other Variables

Variables		**Mean**	**t-value**	**p-value**	**Decision**
Egg tray	WithAirPurifierSystem	125 ppm	38.5	0.000	Significant
	WithoutAirPurifierSystem	447 ppm			
Plastic	WithAirPurifierSystem	139 ppm	99.9	0.000	Significant
	WithoutAirPurifierSystem	696 ppm			
squitoCoil	WithAirPurifierSystem	115 ppm	74.90	0.000	Significant
	WithoutAir purifier system	381 ppm			

Table 3 presents the statistical comparison between scenarios with and without the system deployed in the room. Notably, the t-values for the three variables are 74.9, 38.5, and 99.9, and their p-values are all 0.000. This statistical evidence demonstrates that the air filtration system is highly effective.

Table4. TheSystemCost

QTY	**UNITPRICE**(PHP)	**NAME**	**TOTALPrice**(PHP)
1	400	DUCTAIR VENTILATOR	400
1	55	DUST FILTER	55
1	300	HEPA FILTER	300
1	70	MQ135GASSENSOR	70
1	1,300	DISINFECTANTMACHINE	1,300
1	160	NODEMCU V3ESP8266	160
1	50	WATERFLOWSENSOR	50
1	300	RELAY	300
Total			**Php2,635**

Table 4 presents the components required for the development of the system, along with their respective costs. The quantity of the Duct Air Ventilator and the HEPA filter are each one, and they cost 400 and 300 pesos, respectively. The Dust Filter costs 55 pesos per unit, while the MQ135 sensor costs 70 pesos per unit. The total price of the Disinfectant Machine is 1,300 pesos, while the unit costs of the Node MCU V3 ESP8266 and the water flow sensor are 160 and 50 pesos, respectively. The relay has a quantity of 1 and a price per unit of 300 pesos. This amounts to a total price of 2,635 pesos for the system's components.

CONCLUSIONS

The researcher concluded that the system effectively released fog disinfecting solution and started ventilation and air filter systems automatically. The mobile application monitored air quality and alcohol levels, enhancing transparency and promoting better hygiene practices. The system improved air quality under various environmental conditions, and its low total cost makes it an affordable option for educational institutions. The system's automatic disinfection and air filtration functions supplement manual cleaning routines effectively. The integration of the system with a mobile application for control and monitoring demonstrates potential for enhancements and scalability. Overall, the system successfully identifies and integrates technologies to reduce COVID-19 transmission in the classroom, supporting educational institutions in providing a safer learning environment during the pandemic.

RECOMMENDATIONS

Given the findings and conclusions of the research, it is evident that we must consider a number of crucial avenues moving forward.

1. Continuous testing should be conducted under a variety of conditions and scenarios. Not only will we be able to identify any unanticipated issues with the system, but we will also

be able to resolve these issues and improve the system's overall reliability.

2. Second, we recommend a comprehensive study of the long-term health effects of breathing filtered air. Although tests have demonstrated that the system significantly improves air quality, we should work to understand the system's long-term environmental effects.
3. Thirdly, we suggest expanding the mobile application's user interface. While the current interface provides the necessary capabilities, additional features could enhance the user experience and provide more robust data tracking over time.
4. Finally, investigating alternative energy sources for the system may be advantageous. Considering alternative or backup power sources could improve the system's resilience and dependability, given that it relies on a constant power supply at present. In the event of a power outage, solar power or battery backups could provide an additional layer of security by ensuring the system's continued operation.
5. These suggestions are intended to enhance the system's functionality, user experience, and dependability, while maximizing its potential health benefits.

REFERENCES

Al-Sayah, M. H. (2020). Chemical disinfectants of COVID-19: an overview. Journal of Water and Health, 18(5), 843–848. https://doi.org/10.2166/wh.2020.108

Choi, H., Chatterjee, P., Lichtfouse, E., Martel, J. A., Hwang, M., Jinadatha, C., & Sharma, V. K. (2021). Classical and alternative disinfection strategies to control the COVID-19 virus in healthcare facilities: a review. Environmental Chemistry Letters, 19(3), 1945–1951. https://doi.org/10.1007/s10311-021-01180-4

Domingo, J., & Rovira, J. (2020). Effects of air pollutants on the transmission and severity of respiratory viral infections. ScienceDirect. https://www.sciencedirect.com/science/article/abs/pii/S0013935120305430

Domingo, J., Marques, M., & Rovira, J. (2020). Influence of airborne transmission of SARS-CoV-2 on COVID-19 pandemic: A review. ScienceDirect. https://www.sciencedirect.com/science/article/abs/pii/S0013935120307568

Edwards, D., Salzman, J., Devlin, T., & Langer, R. (2020). Nasal Calcium-Rich Salts for Cleaning Airborne Particles from the Airways of Essential Workers, Students, and a Family in Quarantine. Molecular Frontiers Journal, 4(01n02), 36-45. https://doi.org/10.1142/S2529732520400040

Fishman, L. (2021). Prevent COVID-19: How to Protect Yourself from the Coronavirus. NewYork-Presbyterian. https://healthmatters.nyp.org/how-to-protect-yourself-from-coronavirus-covid-19/

Flores, H. (2021). Duterte Approves Limited Face-To-Face Classes In 120 Public And Private Schools. OneNews.PH. https://www.onenews.ph/articles/duterte-approves-limited-face-to-face-classes-in-120-public-and-private-schools

Ghafoor, D., Khan, Z., Khan, A., Ualiyeva, D., & Zaman, N. (2021). Excessive use of disinfectants against COVID-19 posing a potential threat to living beings. Current Research in Toxicology, 2, 159–168. https://doi.org/10.1016/j.crtox.2021.02.008

Heo, K. J., Park, I., Lee, G., Hong, K., Han, B., Jung, J. H., & Kim, S. B. (2021). Effects of Air Purifiers on the Spread of Simulated Respiratory Droplet Nuclei and Virus Aggregates. International Journal of Environmental Research and Public Health, 18(16), 8426. https://doi.org/10.3390/ijerph18168426

Hirose, R., Bandou, R., Ikegaya, H., Watanabe, N., Yoshida, T., Daidoji, T., Naito, Y., Itoh, Y., & Nakaya, T. (2021). Disinfectant effectiveness against SARS-CoV-2 and influenza viruses present on human skin: model-based evaluation. Clinical Microbiology and Infection, 27(7), 1042.e1-1042.e4. https://doi.org/10.1016/j.cmi.2021.04.009

ILO, FAO, IFAD, & WHO. (2020). Impact of COVID-19 on people's livelihoods, their health and our food systems. WHO. https://www.who.int/news/item/13-10-2020-impact-of-covid-19-on-people's-livelihoods-their-health-and-our-food-systems

Jaafarzadeh, N., Jorfi, S., Ghaedrahmat, Z., Almasi, H., & Zahedi, A. (2020). Transmission Routes of COVID-19 through Air, Water and Wastewater: A Systematic Review. Hamadan University of Medical Sciences. https://www.semanticscholar.org/paper/Transmission-Routes-of-COVID-19-Through-Air%2C-Water-Jaafarzadeh-Jorfi/c7896e68fb5ad3a58e79ed72cb318652dbfb2d09

Ma, J., Du, M., Wang, C. et al. (2021). Advances in airborne microorganisms detection using biosensors: A critical review. Front. Environ. Sci. Eng. 15, 47. https://doi.org/10.1007/s11783-021-1420-8

MaRS Discovery District. (2013). Product Development: The Waterfall Methodology (model) in Software Development. MaRS Startup Toolkit. https://learn.marsdd.com/article/product-development-the-waterfall-methodology-model-in-software-development/

Moelling, K., & Broecker, F. (2020). Air Microbiome and Pollution: Composition and Potential Effects on Human Health, Including SARS Coronavirus Infection. Journal of Environmental and Public Health, 2020, 1646943. https://doi.org/10.1155/2020/1646943

Panicker, D. (2020). Smart Air Purifier with Air Quality Monitoring System. International Journal for Research in Applied Science and Engineering Technology, 8(5), 1511–1515. https://doi.org/10.22214/ijraset.2020.5244

Peladarinos, N., Cheimaras, V., Piromalis, D., Arvanitis, K. G., Papageorgas, P., Monios, N., Dogas, I., Stojmenovic, M., & Tsaramirsis, G. (2021). Early Warning Systems for COVID-19 Infections Based on Low-Cost Indoor Air-Quality Sensors and LPWANs. Sensors, 21(18), 6183. https://doi.org/10.3390/s21186183

Rai, N. K., Ashok, A., & Akondi, B. R. (2020). Consequences of chemical impact of disinfectants: safe preventive measures against COVID-19. Critical Reviews in Toxicology, 50(6), 513–520. https://doi.org/10.1080/10408444.2020.1790499

Ribeiro, M. M., Neumann, V. A., Padoveze, M. C., & Graziano, K. U. (2015). Efficacy and effectiveness of alcohol in the disinfection of semi-critical materials: a systematic review. Revista Latino-Americana de Enfermagem, 23(4), 741–752. https://doi.org/10.1590/0104-1169.0266.2611

Richey, R. C. (1993). Developmental Research: The Definition and Scope. ERIC. https://eric.ed.gov/?id=ED373753

Sarmiento, P. J. D., Sarmiento, C. L. T., & Tolentino, R. L. B. (2021). Face-to-face classes during COVID-19: a call for deliberate and well-planned school health protocols in the Philippine context. Journal of Public Health, 43(2), e305–e306. https://doi.org/10.1093/pubmed/fdab006

Sodiq, A., Ali Khan, M. et al. (2020). Addressing COVID-19 contagion through the HVAC systems by reviewing indoor airborne nature of infectious microbes: Will an innovative air recirculation concept provide a practical solution? Environmental Research. https://reader.elsevier.com/reader/sd/pii/S001393512100623X?token=3FF297300FCFE6E6F2007263580E18A4E9B266919983C89769ABCBE875B065993D31417DB349DCB44641CDA44DCD20FE&originRegion=us-east-1&originCreation=20211010054013

The World Air Quality Index Project. (n.d.). Air Quality Index Scale and Color Legend.

United Nations. (2020). Protecting and mobilizing youth in COVID-19 responses. Department of Economic and Social Affairs Youth. https://www.un.org/development/desa/youth/news/2020/05/covid-19/

Wang, C., Song, L., Wang, X., et al. (2020). Aerosol transmission, an indispensable route of COVID-19 spread: case study of a department-store cluster. https://www.semanticscholar.org/paper/Aerosol-transmission%2C-an-indispensable-route-of-of-Jiang-Wang/d361ea1153393ddbae7240bfba7d0aec1f5deb0e

World Health Organization. (2020). Coronavirus. https://www.who.int/health-topics/coronavirus#tab=tab_1

Zhai, Z., Li, H., Bahl, R., & Trace, K. (2021). Application of Portable Air Purifiers for Mitigating COVID-19 in Large Public Spaces Buildings, 11(8), 329. https://www.mdpi.com/2075-5309/11/8/329

Zhang, R. (2020). Identifying airborne transmission as the dominant route for the spread of COVID-19. PNAS. https://www.pnas.org/content/117/26/14857#sec-5

Zhao, J., Zhou, B., Butler, J. P., Bock, R. G., Portelli, J. P., & Bilén, S. G. (2021). IoT-Based Sanitizer Station Network: A Facilities Management Case Study on Monitoring Hand Sanitizer Dispenser Usage. Smart Cities, 4(3), 979–994. https://doi.org/10.3390/smartcities4030051