Journal of Chemical Health Risks

www.jchr.org

JCHR (2023) 13(4), 860-867 | ISSN:2251-6727

IOT based Microorganism Detection and Filtration System

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(Received: 02 September 2023 Revised: 14 October Accepted: 07 November)

KEYWORDS

IoT,
Microorganisms,
Air Quality,
Real-Time Monitoring,
Filtration system

ABSTRACT:

The Internet of Things (IoT) has enabled the devel- opment of innovative solutions in various fields, and one of the promising applications is in the area of microorganism particle filtration. In this study, an IoT-based system for microorgan- ism particle detection and filtration and efficiency testing was developed. The system uses a microorganism particle filtration device equipped with sensors and actuators that enable real- time monitoring and control of the filtration process. The IoT platform allows for remote monitoring and data collection, which can be used to optimize filtration efficiency and reduce operating costs. Efficiency testing was carried out by introducing known concentrations of microorganisms into the filtration system and measuring the reduction in concentration at the outlet. The results showed that the system was able to effectively filter microorganisms with a high degree of efficiency, and the IoT-based platform provided valuable insights into the filtration process. According to our findings in this study, we achieved almost 90% efficiency applying the filtration system in the K95 and the surgical mask after it had been used for 6-7 hours, which is closer to the initial efficiency of 95%. Thus, it can be used a second time but after that, the efficiency drops, and it is recommended not to use. Overall, the IoT-based microorganism particle filtration and efficiency test system presented in this study has the potential to revolutionize the field of microorganism filtration, providing a cost-effective, efficient, and sustainable solution for a wide range of applications.

I. INTRODUCTION

The COVID-19 pandemic has emphasized the importance of personal protective equipment (PPE), particularly face masks, in preventing the spread of infectious diseases. However, not all face masks are created equal, and their effectiveness in filtering microorganism particles varies. Therefore, it is crucial to develop reliable methods for testing the efficiency of face masks in filtering microorganism particles. The Internet of Things (IoT) has the potential to revolutionize the field of face mask filtration efficiency testing. IoT-based systems can provide real-time monitoring and control of the filtration

process, improving the precision and accuracy of testing. Moreover, the IoT platform enables remote monitoring and data collection, which can be used to optimize filtration efficiency and reduce operating costs. In recent years, there has been growing interest in developing IoT-based systems for face mask filtration efficiency testing. These systems use sensors, actuators, and other IoT technologies to measure the concentration of microorganism particles before and after passing through the face mask, allowing for accurate determi- nation of the filtration efficiency. In this context, this paper aims to present an IoT-based microorganism particle filtration and efficiency testing system for face masks. The system's development and experimental results will be discussed in detail, highlighting its effectiveness, efficiency, and potential applications. Overall, the IoT-based face mask filtration effi- ciency testing system presented in this study has the potential to revolutionize

Journal of Chemical Health Risks
www.jchr.org
JCHR (2023) 13(4), 860-867 | ISSN:2251-6727

the field of PPE, providing a cost-effective, efficient, and sustainable solution for ensuring the safety of individuals and preventing the spread of infectious diseases.

II. LITERATURE REVIEW

Since December 8, 2019, Wuhan, Hubei province, China has reported several pneumonia cases, primarily from workers at the Huanan seafood wholesale market [1]. To ensure safety, a particle filtration efficiency tester was developed. A Parti- cle Generator 8026 (TSI) was used to enhance surrounding particles in a chamber, with sodium chloride particles having a count middle measurement of 0.05 micrometers. Particle concentration in the chamber was allowed to balance out for 30 minutes before testing. All face masks were fitted with testing tests using a Fit Test Probe Kit for Disposable face mask 8025-N95 (TSI). Condensation Particle Counters 3775 (TSI) were run in single particle analysis mode to continuously monitor particles in the chamber outside and behind the face mask at a 1-second examining pace. Ten feet of conductive elastic tubing were used for each testing

line, and a small piece of nonconductive tubing and stopcock was filled in as a connector between the testing port and the conductive tubing testing line. The temperature during testing ranged from 23°C to 29.5°C, and the overall moisture was 10-50(%). The average FFE(Fitted Filtration Efficiency) was found to be the middle value from the beginning to the end of the testing time, and the normal standard deviation over the time of testing was registered. Three respiratory disinfection strategies were tested on used veils: ethylene oxide (EtO), steam (121°C, 15 minutes), and disintegrated hydrogen peroxide (8 g/min, 260 PPM, 100-minute cycle). A Controlled Air Purifying Respirator (MAXAIR) with a face shield prevented 99.99(%) of particles from entering the test person's breathing space. N95 respirators with exhalation valves had FFEs over 95.9(%), while N95 respirators not commonly used in medical settings had FFEs over 95.0(%)[2]. Of the seven different varieties of particulate filtering facepiece respirators, the N95 respirator is the most popular. Although this device filters at least 95(%) of airborne particles, it cannot withstand particles made of oil [3]. Standard testing techniques for masks and substances often involve testing them under the worst-case scenario and conservative conditions. This requires extensive engineering design, flow match, isokinetic sampling, and instrumentation. Evaluation criteria can be adjusted to provide a preliminary estimate. Efficiency estimates use the number concentration of test particulates as a quantitative parameter. The size distribution of steady-state atomized NaCl particles varies between studies. The flow rate for aerosol capture efficiency and pressure drop is set at 28.3 Lmin, which is higher than the average adult's normal respiration rate and mild exercise respiratory rate [4]. Face velocities for intrinsic measurements are 19.86 cm/sec, while complete mask velocities are 1.88–2.36 cm/sec [5]. The filter material's pressure drop is measured at 8 Lmin, and the sampling flow rate for the 'fit test' on the mask sampler is set to 0.3 Lmin [6]. Error propagation techniques were used in the study to evaluate the capture effectiveness of N-95 respirators and surgical masks. The filtration efficiency pattern for the N-95 respirator and surgical mask was U-shaped, with a minimum of about 0.3 m. The fabric mask, on the other hand, exhibited a low efficiency in the 0.06-0.14 m particle size range. For these masks, the efficiency was assessed at 96.94(%), 52.44(%), and 8.27(%), respectively. Due to the shape and size features of the coronavirus, the efficiency in the 0.06-0.14 m range is predicted to be similar to the viral capture efficiency [7]. The setup and experimental technique were more adaptable and practical for first evaluations, although the experimental test settings were comparable to standard practices. The use of polycrystalline test aerosol systems, number concentration as a testing parameter, flexibility in face velocities, and the ability to evolve in-house methodology were primary differences compared to established standardized procedures. These test conditions are simple to achieve and can be implemented quickly during the design and development phase. The main vision is to establish a reusable system to reduce harmful disposal masks and create a cost-efficient system for face mask use, while also raising awareness.

III. OVERVIEW AND WORKING PRINCIPLE OF THE PROPOSED SYSTEM

IOT-based particle filtration as in this approach sensors will be controlled via WiFi capable IoT (Internet of Things) controller which is used for data transfer via

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JCHR (2023) 13(4), 860-867 | ISSN:2251-6727

serial commu- nication. In Figure 1, we have a flow diagram for an IOT- based particle filtering system. Comparing cloud data sets to one another is currently a popular monitoring survey approach for analyzing the particle filtration efficiency of masks. Using the AQI sensor to obtain data sets allows us a comprehensive output, to clearly measure, analyze, and show any change between surveys over time [8].

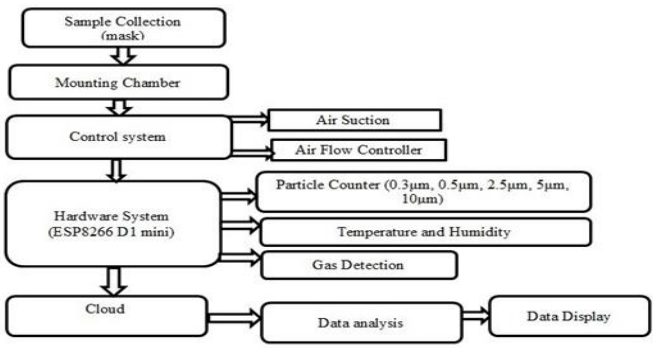

Fig. 1. Illustrates the workflow of the fault detection classification method- ology.

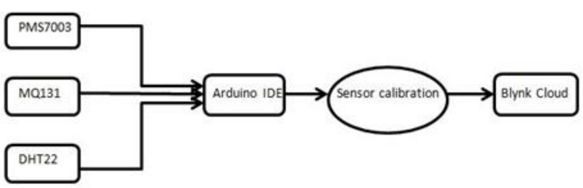

Fig. 2. Workflow of selected tools for the final prototype.

In Figure 2, we've displayed a workflow for the final prototype's chosen tools. We had to calibrate and sync our sensors for our final prototype. In the Arduino IDE, we had to download libraries for the ESP8266, Arduino, DHT, PMS7003, and MQ131. Then, we had to calibrate our sensors so they could collect data, and we used a cloud server for display. When everything was finished, we could access our data in the Blynk cloud.

We further used proteus for a simulation model of IOT-based particle filtration. Because Proteus or any other program does not support it, a variable resistance was utilized to represent a particle counter sensor together with another Arduino Uno and a servo motor to imitate a vacuum pump (because we wanted to control this system by controlling the pressure). An Arduino Uno is attached to a buzzer, which measures

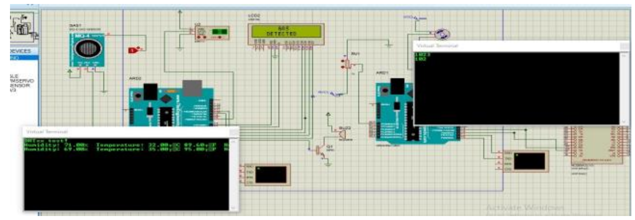

Fig. 3. Simulation result of IOT Based Particle Filtration.

temperature and pressure. An MQ-4 gas sensor measures ozone gas. Additionally, because the NODEMCU can save data to a cloud server, we developed it to replace our ESP8266 D1 mini. Finding the tiniest particle is our objective here, and we want to save the information for later use. As soon as the simulation began, like Figure 3 we could see the temperature and pressure values in the terminal, and when ozone gas was identified, the buzzer began to beep and the LCD display displayed "gas detected." Now, when the motor began to turn and the variable resistance was at its lowest, it would give a defined minimum range of particles that the system would suction until we kept it at its highest. Additionally, the particle suction range would expand to its maximum when the value has reached its highest. Although the particle counter sensor's primary function is to measure particle size and count them, the proteus lacks this sensor, making it impossible to determine how many particles were sucked through the device. Just like our hardware prototype, we were able to change the range of the particle sucked through the device by adjusting the servo motor.

IV. HARDWARE IMPLEMENTATION AND DESIGN CONSIDERATION

A. *Design Methodology and process*

Fig. 4. Full set-up of IoT-Based Microorganism Detection

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JCHR (2023) 13(4), 860-867 | ISSN:2251-6727

and Filtration System

It is essential to keep an eye on the decline in particulate concentration to gauge how well therapeutic coverings and respirators are working by determining how well the particles are moving through the channels. A sheet of the cover fabric must be exposed to a flux of 0.3 µm-sized particles (for N95)

in order to conduct a veil filtration productivity test setup. The throughput of these particles across the veil must then be measured. For a desired molecule measurement, commercial setups often feature built-in vaporized generators, however residual sub-micron and micron-sized particles are frequently present in room air and can be employed instead. For air quality estimations, air-quality indicator (AQI) frameworks are frequently utilized, especially in polluted cities. The Plantower PMS 1003/5003/7003 series, which provides measurements of molecule checks at 0.3, 0.5, 1, 2.5, 5, and 10 µm as standard yields, is one of the laser particle counter sensors that several AQI frameworks are based on. These sensors have undergone thorough testing and are optimized for the detection of 2.5 µm measured particles. In a university research and development facility, a system was put up to use a PMS7003 molecule counter to distinguish between the positions of particles in containers measuring 0.3, 0.5, 1, 2.5, and 10 µm. An XZ- 1A vacuum pump, air control valve, PVC board, oval-shaped ball, vent hole "mouth," N95 respirators, and connecting pipes through the chamber to the data gathering box and pump were used to create the air traveling through the PMS7003. The Arduino IDE and C programming language were used to create the sensors.

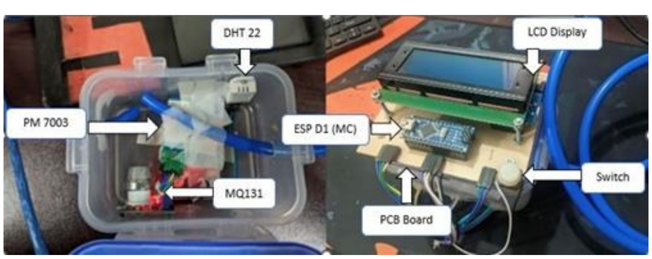

Fig. 5. Data collection box (PMS7003,DHT22,MQ131)

Images of the data collection device are shown in Figure 5. We also had to keep an eye on the temperature and humidity in addition to the particles. Our research and development facility has a UV-light disinfection chamber. Using the MQ131 sensor, we have been studying the Ozone range. The Plantower PMS7003 sensor, a DHT22, and a MQ131 make up our cover PFE test setup. On a small scale, they are all controlled by an ESP D1 WiFi microcontroller unit controller with an Arduino nano center compatible with the Arduino IDE. The ESP D1 small board's regular micro-USB port is used to remotely power the device.

B. Data Collection and Monitoring

To monitor the data in a cloud server, we are using the BLYNK server shown in Figure 6, which is an Internet of Things platform for iOS or Android devices that allows users to remotely operate Arduino, Raspberry Pi, and NodeMCU over the Internet. We designed the Blynk server in such a way that it can monitor the amount of particles, efficiency, and Ozone gas. Also, this server stores previous data and also shows the previous efficiency results. Figure 7 shows how we view our data on the LCD display which is a flat-panel display

Furthermore, to find the Particle Disinfection (%) of the disinfected mask (D_{mask}), we used the below formula:

$$x = \frac{N_{mask}P_{avg} * D_{mask}P_{avg}}{100}$$

Fig. 6. BLYNK cloud server for monitoring data and efficiency

or other electronically controlled optical device that makes use of polarizers and the light-modulating capabilities of liquid crystals is known as a liquid-crystal display (LCD).$Disinfection(\%) = (N_{mask\ Disinfection(\%)} - x)$ (5)

We set out to assess the surgical mask's performance initially. The data was then taken and entered into Table II after 6-7 hours of mask use. As more particles are present on the mask surface, our system is able to identify

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JCHR (2023) 13(4), 860-867 | ISSN:2251-6727

more of them, according to the data.

TABLE II. Data after using masks 6-7 hours

Data	pm 0.3μm	pm 0.5μm	pm 1μm	pm 2.5 μm	pm 5μm	pm 10μm	Particle Disinfection (%) (%)
13/12/2022	118	107	90	88	92	83	89.94
13/12/2022	110	100	98	98	85	84	90
13/12/2022	100	98	98	89	88	84	96
14/12/2022	118	120	105	98	96	87	89
14/12/2022	112	110	104	94	94	89	89.45
14/12/2022	100	100	98	88	83	80	92

Result

Fig. 7. Data display in LCD

V. Result and Discussion

VI. We collected the data after disinfecting the used mask, which is shown in Table III.

We cleaned the mask using our sterilization chamber. Both the interior and exterior of the disinfection chamber are shown in Figure 8. We took the data again to confirm that

In order to assess the air quality in the R (&) D lab, we first gathered data for surgical masks and KN95 masks numerous times. However, the best three values are displayed in Table

I. We used the average figure since we planned to use those numbers as a benchmark for evaluating the performance of the mask.

TABLE I. Data after placing New masks in chamber

Data	pm 0.3μm	pm 0.5μm	pm 1μm	pm 2.5μm	pm 5μm	pm 10μm	Ozone(ppm)
13/12/2022	21	14	10	10	5	4	0.00
13/12/2022	16	11	13	7	6	3	0.00
14/12/2022	25	16	10	7	5	6	0.00

To find the Particle Disinfection (%), we first calculated the particle (P) average that was found on the new mask (N_{mask}) and also on the mask that has been used for 6-7 hours (U_{mask}) using the below formula:

Σ P the mask had been thoroughly cleaned after disinfecting it. After investigation, we discovered that our instrument only picked up very few particles, indicating that our disinfection chamber is operating as intended. Additionally, while using the disinfection chamber, we found 0.02ppm of ozone gas. We are able to determine the (%) of particle disinfecting using our data table.

Fig. 8. Disinfecting chamber

TABLE III. Data After disinfecting mask

Date	pm 0.3μm	pm 0.5μm	pm 1 μm	pm 2.5μm	pm 5μm	pm 10μm	Ozone(ppm)	P.Disinfection (%)
13/12/2022	60	0	0	0	0	0	0.02	100
13/12/2022	72	25	8	10	10	0	0.02	97.8
13/12/2022	60	36	25	12	14	5	0.02	97
14/12/2022	71	30	15	5	13	12	0.02	97.4
14/12/2022	62	15	20	10	8	11	0.02	98
14/12/2022	65	20	5	8	11	15	0.02	97.9

After getting the particle average of both masks we used the formula below to find the Particle Disinfection (%) of the used mask (we assume the efficiency of the new mask to be 100):

$$x = \frac{N_{mask} P_{avg} * U_{mask} P_{avg}}{100} \quad (2)$$

We utilized the same mask for a second time for 6-7 hours and followed the same procedure to determine

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the mask's

$$Disinfection(\%) = (N_{mask\ Disinfection(\%)} - x) \quad (3)$$

effectiveness.

TABLE IV. Data after disinfecting and reusing 6-7 hours

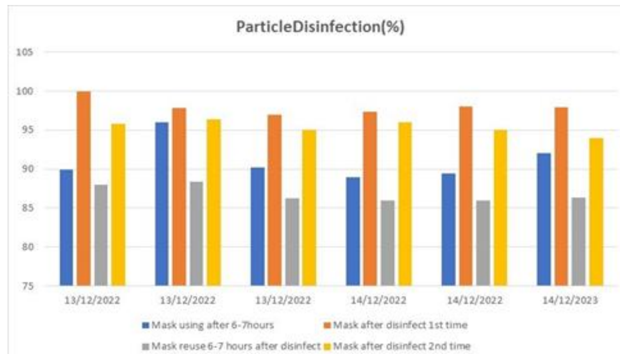
Date	pm 0.3μm	pm 0.5μm	pm 1 μm	pm 2.5μm	pm 5μm	pm 10μm	Ozone (ppm)	P. Disinfection (%)
13/12/2022	137	128	125	117	107	93	0.00	88
13/12/2022	145	125	105	98	99	89	0.00	88.4
13/12/2022	172	163	145	111	96	92	0.00	86.3
14/12/2022	166	148	139	123	115	110	0.01	85.94
14/12/2022	167	159	147	131	117	90	0.01	86
14/12/2022	161	149	132	122	119	97	0.01	86.35

TABLE V. Data After disinfecting the mask for the second time

Date	pm 0.3μm	pm 0.5μm	pm 1μm	pm 2.5μm	pm 5μm	pm 10μm	Ozone (ppm)	P. Disinfection (%)
13/12/2022	75	65	39	25	23	12	0.02	95.81
13/12/2022	70	54	27	27	19	8	0.02	96.41
13/12/2022	88	67	24	32	16	11	0.02	95
14/12/2022	64	61	57	24	18	13	0.01	96
14/12/2022	71	64	44	36	24	15	0.01	95
14/12/2022	88	76	59	45	33	29	0.02	94

Table VI represents the data after disinfecting the mask again.

To determine the effectiveness of the KN95 mask and to identify the particles, we used the same process. We only displayed the results for the surgical mask because the KN95 and those figures were quite comparable.



9. Particle Disinfection (%) Comparison

After looking at different particles, we assessed the effec- tiveness of masks in Figure 9. After utilizing the mask for 6-7 hours, the examination revealed that the proportion of particles that were disinfected had decreased by an average of 90(%). After further cleaning and use of the mask for 6-7 hours, its performance once more declined by an average of 86 (%).

Fig. 10. Graphical representation of Ozone gas and device placed inside disinfecting chamber

We also put an observation on Ozone gas. After using a disinfecting chamber we found a small amount of Ozone gas present in the room and inside the chamber which is 0.02ppm which is shown in Figure 11. This small amount of Ozone gas is not that harmful to human beings. UV light, a form of radiation that can pass through the protective layers of organisms like skin, is well-trapped by ozone. In turn, this might harm animal and plant DNA molecules. UVB and UVA are the two main subtypes of

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UV light. Skin diseases like sunburns and malignancies like basal cell carcinoma and squamous cell carcinoma are brought on by UVB nv[9]. So we need to ensure safety in terms of using a disinfection chamber.

A. Discussion

To protect against COVID-19, using a worn mask may be more hazardous than not wearing one at all, according to a recent study. According to a study published in the Physics of Fluids, a novel three-layer surgical mask is 65 percent effective in filtering airborne particles, but when it is worn, that efficiency falls to 25 percent. A dirty face mask can't efficiently filter even the smallest drops, according to researchers from the University of Massachusetts Lowell and California Baptist University, who also claim that masks slow down airflow, leaving people more prone to breathing in particles [10]. So according to research, it is risky to reuse the mask as the performance drops after using it one time.

TABLE VI.Analysis of mask efficiency

Name of mask	Particle Disinfection(	Condition
Surgical mask	95	New mask
	89-92	after using 6-7 hours
	84-86	after 2 time use
KN95	95	New mask
	89-92	after using 6-7 hours
	84-86	after 2 time use

In Nebraska, 4,705 COVID-19 tests were conducted in the week ending September 23, 2023, yielding 504 positive findings. The optimism rating is 10.7(%), which is 0.2(%) lower than the previous week [11]. Therefore, COVID-19 is still ongoing, and using a mask is necessary for our own protection. Our main objective for this project was to success- fully check the filtration effectiveness of both surgical masks and KN95 masks before and after disinfection. Although the mask has a fair efficiency rate, it nevertheless loses efficiency significantly with time. Reusing masks is damaging, thus we advise against doing so in order to maintain safety. Instead, make sure any mask is effective before using it.

VII. CONCLUSION

The increasing prevalence of illnesses is primarily due to pollution, dust, and viral agents. To mitigate infection risks, high-quality protective masks are essential. However, affordability often presents financial challenges for many. The COVID-19 pandemic has highlighted the consequences of unemployment and lax safety protocols, leading to a surge in coronavirus cases. To address this, research has focused on the efficacy of protective masks and developing a particle filtration method. The institution's research and development laboratory houses a specialized disinfection chamber, requiring recurrent assessments of its disinfection efficiency. To address accessibility and cost-effectiveness challenges, an approach has been developed to facilitate the reuse of protective gear post-disinfection. Comprehensive testing has shown the via- bility of reusing safety kits and masks, with the added benefit of securely storing and accessing efficiency test results and data in cloud-based repositories. The particle filtration effi- ciency testing setup holds promise for deployment in hospitals, catering to both business and healthcare needs. This holistic solution enhances sustainability and reduces project costs through the judicious allocation of time, labor, and resources.

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