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Arduino-based Air Quality Testing, Air Filtering and Disinfecting Device Design and Effectivity testing for Hospital Rooms

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***Abstract*—** Establishing a therapeutic environment is one of the most important responsibilities of a nurse especially in hospital setting and this responsibility extends on keeping the environment clear from pathogens, dust, debris, and other pollutants. This study is conducted to design and test the Arduino-based air filtering and disinfecting device prototype and evaluate the air quality of the hospital rooms on selected hospitals in Iligan City. The Operating Room, OR Major Room, and OR OB Room were tested in these hospitals. The device utilizes a pre-filter, HEPA filter, activated carbon filters, germicidal lamp, Arduino Uno board, and a gas sensor. The testing phase showed a decrease on the number of colonies on the nutrient agar test which was conducted pre and post filtering process as well as the accuracy of detecting Environmental effluence.

***Keywords*—** *Arduino; Air Filtering Device; Air Quality Index Air Disinfecting Device*

I. INTRODUCTION

The healing process is a complex procedure that involves a lot of factors. The patient's physical condition, prognosis, medications, procedures performed, and environmental control should be taken into consideration. In a hospital setting, same factors hold a significant truth but the fact that the patient is exposed to more pathogens and pollutants, controlling the environment especially the air should not be taken for granted. Among these factors, the health care team focuses more on the medical aspects of the healing process, and although the team is aware of the effects of the environment on a patient, the fact that this places the patients at risk as well as the medical team is usually sidelined to give way to the more important aspects of healing and recovery [1].

In a hospital setting, it is important to maintain the air quality in a therapeutic level for the reasons of client and medical personnel safety. Indoor air Quality (IAQ) encompasses a wide variety of factors: temperature, humidity, quantity and presence of chemicals and other contaminants, and the quality of outdoor air brought inside are typical metrics used to define the IAQ. In the efforts of providing good quality air, most hospitals in the Philippines would settle for the use of disinfectant sprays. This practice has 3 obvious problems: 1. Most of these sprays have a strong offensive smell and somehow produces a certain kind of discomfort for patients and hospital personnel, 2. Although effective at the onset, these chemical sprays would eventually wear off after a few hours, 3. It is obviously not environmental- friendly.

Therefore with these factors in mind, the researchers aimed to design and develop and Arduino-based air quality testing, air filtering, and air disinfecting device for hospital rooms using a pre filter, a High Efficiency Particulate Air (HEPA) filter, activated carbon filter and a UV lamp. The device also has hazardous gas and dust sensors to detect harmful agents in the room. This will meet air quality standard for particulate matter measuring 2.5micrometers in diameter and smaller or commonly known as PM 2.5 set by DENR. The microcontroller included in the device will act as a monitoring system program to monitor the gas level and the air quality index in the area.

II. RELATED STUDIES

Air Pollution Index (API) Real Time Monitoring System by Ruslan, N. This project was aimed to develop a low cost, mobile Air Pollutant Index (API) Monitoring System, which consists of Sharp GP2Y1010AU0F optical dust detector as a sensor for dust, ArduinoUno and LCD Keypad Shield. A signal conditioner was used to amplify and extend the range of the sensor reading for a more accurate result. Readings from the sensor has been compared with the reference data from the Department of Environment, Malaysia. The developed dust detector is expected to provide a relatively accurate API reading and suitable to be used for the detection and monitoring of dust concentrations of industrial areas around Parit, Raja, Johor. The researchers used the concept of optical dust detector as a sensor for dust and Arduino micro controller to be the brain of the air quality testing, filtering and disinfecting device.

A study entitled The Importance of Bioaerosols in Hospital Infections and the Potential for Control using Germicidal Ultraviolet Irradiation. Ultraviolet germicidal irradiation is now a recognized method of inactivating a wide variety of biological agents (Rice & Ewell, 2001) and in particular airborne microorganisms. Recent increases in the incidence of airborne diseases such as tuberculosis have focused attention upon the use of this technology and in the USA ultraviolet disinfection systems are currently widely used in hospitals and other health care environments in order to protect patients and healthcare workers (Dumyahn & First, 1999). It has previously been noted in the literature that the efficacy of UV irradiation is a function of many different location and operational factors including UV intensity, exposure time, lamp placement, air movement patterns and the relative humidity of the air (Lin & Li, 2002; Peccia et al, 2001; Ko et al, 2000). Microorganisms are particularly vulnerable to UV light at wavelengths close to 254nm since this represents the maximum absorption wavelength of their DNA molecule. Photons of UV light strike a biological cell and the energy is absorbed by nucleic acids in the DNA molecule leading to the formation of pyrimidine dimers and other lethal photoproducts (Beggs 2002). The formation of pyrimadine dimers leads to changes to the double helix structure, cell mutation and ultimately to the death of the cell.

Another study entitled Efficacy of antimicrobial filter treatments on microbial colonization of air panel filters aims to assess the activity of biostatic agents on the microbial colonization of panel filters. Microfiber glass acrylic filters, both used and unused, were examined for the presence of

microorganisms. Test strains were used to verify microbial colonization of filter media. Antimicrobial agents were applied to the filter media and tested for their ability to reduce microbial colonization. The integrity of the panel filters and the antimicrobial activity trends of the filter media treated with antimicrobials were verified. A filtration efficiency test was carried out on the treated filters to evaluate filtration performance. Filters treated with antimicrobials demonstrated markedly less microbial colonization (density and varieties of species), higher filtration efficiency and delayed deterioration of the filter. The most important results of this study are the demonstration of preservation of the integrity of the filters and the lower release of microorganisms from treated filters. These results contribute to the resolution of problems concerning the microbial contamination of panel filters in the heating, ventilating and air-conditioning systems commonly used in the electronic industry, pharmaceutical industry, hospitals and other environments where the absence of contaminating particles and microorganisms is required (Verdenelli, Cecchini, Orpianesi, G.M., & Cresci, 2009).

Comparison between various Technologies are shown on Figure 1 below.

Device	Number of Filters	Process of Filtering/ Disinfecting	Cost	Additional Features other than filtering
Arduino-based device	4	Pre-filter, HEPA filter, Activated carbon and UVG lamp	Php 15,392	Air Quality analyzer
Commercial Device 1	2	Carbon Filter, HEPA filter	Php 24,497	none
Commercial Device 2	4	Pre-filter, HEPA filter, Carbon Filter and Optional V.O.C. Canister	Php 156,796	none

III. DEVICE DESIGN AND TESTING METHODS

The Figure 2.1 and Figure 2.2 below show the proposed design of the device

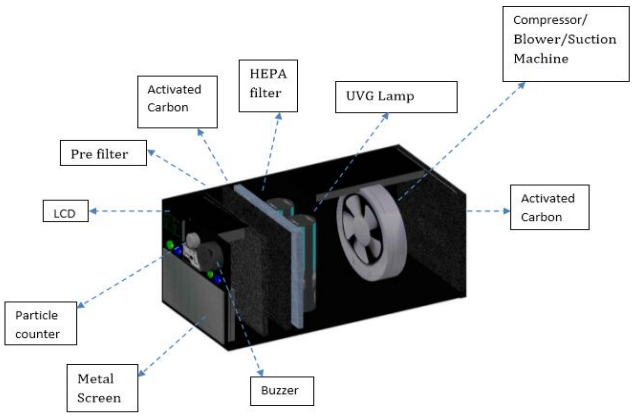

Figure 2.1

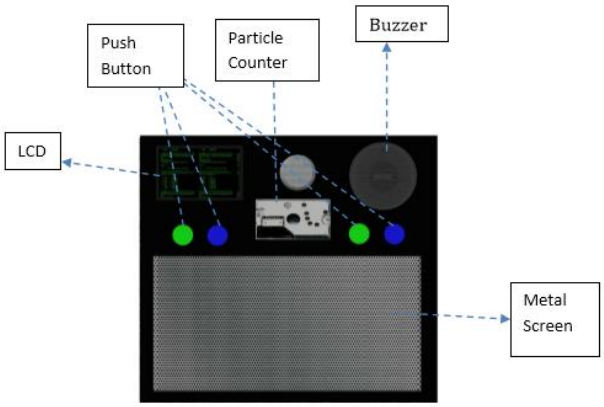

Figure 2.2

The proposed internal components and stages of filtering are shown on Figure 3

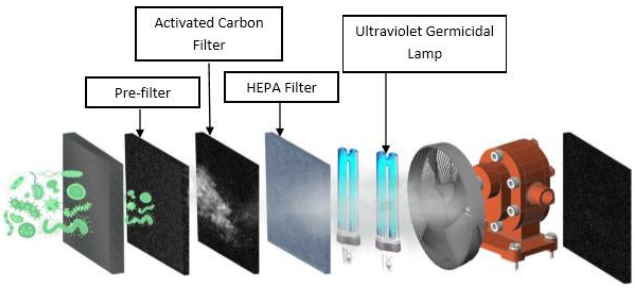

Figure 3

The study involves 3 phases, designing phase, laboratory testing phase: Filtering verification test, and Clinical Trial. Filtering Verification tests were done at the School of Computer Studies Laboratory, MSU-IIT. The clinical trials were then done at Gregorio T. Lluch Memorial Hospital (GTLMH) and Adventist Medical Center (AMC) inside the Operating Room, OR Major Room, and OR OB Room.

IV. RESULTS AND PERFORMANCE ANALYSIS

To determine the effectiveness of the device to filter and disinfect pathogens, nutrient agar tests were done pre and post clinical testing. Although the study does not involve in the identifying the type of pathogen, Figure 4 shows the decrease of colonies in the agar after the filtration and disinfection process.

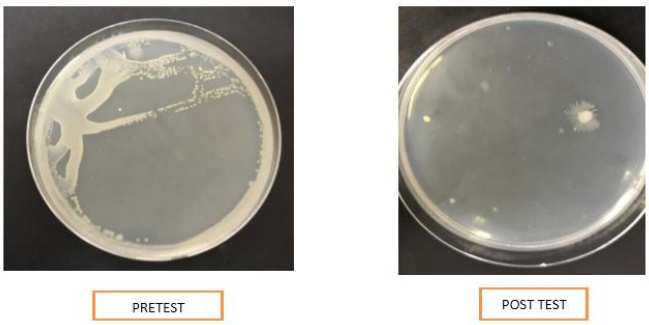

Figure 4

Figure 5 shows a comparative Frequency Distribution of Colony Count Before and after AQT, filtering and disinfecting process

Area	Before	After	Difference	Percentage
OR GTLMH	40	17	23	57.50%

(am)				
OR GTLMH (pm)	48	18	30	62.50%
OR MAJ AMCI (am)	29	13	16	55.17%
OR MAJ AMCI (pm)	18	13	6	27.78%
OR OB AMCI (am)	26	10	16	61.53%
OR OB AMCI (pm)	23	13	10	43.46%

Figure 5

In testing the accuracy of sensors in detecting Environmental Effluence, the researchers used spray paint can, cigarette smoke, dust and insecticide spray during the testing phase. Each of the samples have different values in terms of the highest air quality index and gas level obtained however, by average in about 5-10 minutes, all tested gases have lowered to a therapeutic "good" level. During the clinical trial, all tested hospital rooms were expected to be free from harmful gases as these areas were considered "restricted" and "sterile" therefore showed a unanimous "good" Air Quality Index (AQI) Figure 6 shows the LCD display of the device after running air diagnostics in the room during testing phase

Figure 6

CONCLUSION

Developing the Air filtering and disinfecting device shows a significant importance with regards to keeping the environmental air safe and therapeutic not only to the patients in the hospital but also the hospital staff. The combination of filters and a UV disinfectant proves to be effective in minimizing pathogens during the clinical trials. Evaluating environmental effluence with the use of the Arduino Uno board and sensors also prove to be accurate in measure the Air Quality Index of hospital rooms with regards to certain chemicals such as paint, cigarette smoke, and insecticides. This device can be utilized not only in hospitals but on other related industries.

Acknowledgment

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