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An Intelligent Wearable Real Time based Black Soot Monitoring and Alerting System in Nigeria

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Abstract— *this paper presents a wearable real-time-based black soot monitoring and alerting system in Nigeria. It is no longer news of black soot on air in most parts of Nigeria because of the economic meltdown caused by greedy politicians and bad Governance. These have caused lots of hardship to her citizens and made them start looking for survival by jumping into various kinds of businesses and floating companies without considering the health implications. This development has caused lots of deaths and needs to be monitored to stop it from damaging necessary organs of the human body. Hence, this research work is aimed at developing a wearable soot monitoring device that checks the air quality in any environment and alerts the user of the presence of black soot and its health implications via alarm for necessary actions. The embedded system was designed by integrating sensors to measure the air quality parameters and send them to the controller. The controller checks the quality of the air by determining the quantity of black soot presence and alerts the user via the wearable device's display. The device was constructed and tested with successful results.*

Keywords*—Black Soot, embedded system, Nigeria, Wearable.*

I. INTRODUCTION

The emergences of industries, automobiles, and kpo-fire in Nigeria have made black soot pollution prevalent which has caused a significant impact on humans' health than before. Companies are being floated without considering the by-product of energy generated to human health. All these are dangerous to human health and cause health-related problems like lung-related diseases, namely respiratory problems, cardiovascular disease, and cancer. Accurate monitoring of the black soot on air to determine the quality to save lives is of great importance. It is a major air pollutant that has adverse effects on the environment, made up of carbon, produced by incomplete combustion of coal, oil, plastics, wood, household refuse, or other fuels. There are many adverse environmental impacts from the use of fossil fuels (e.g. oil and coal) as an energy source, such as the release of pollutants and resource depletion. The fine black or brown powder that makes up soot may contain several carcinogens, including arsenic, cadmium, and chromium. The continual burning of fossil fuels causes an increase in environmental pollution, due to CO_2 emissions and other gases that cause global warming through the greenhouse effect. Major sources of emission from Petroleum industries are the implication of black soot and possible ways of surviving the adverse effects from the phenomenon is a big concern as stated in [1].

To assess the perception of residents of the country on the current soot pollution, a cross-sectional study was undertaken via an online survey among people residing in the state who were literate and had access to internet-enabled devices. Results indicated that most respondents (81.5%) were aware of the soot pollution and perceived the main causes of soot to be artisanal refining of crude oil (87.8%) and burning of confiscated crude oil and its products (76.5%). The majority also perceived that the soot had caused them chronic cough (69.9%) and irritation to the eyes, nose, and throat (64.2%). Female respondents were significantly more likely (Annual Operating Report AOR =1.38 CI = 1.02, 1.86) to complain of a health effect from soot pollution. There is a critical need to investigate and identify sources of soot and mitigate possible impact. Public health campaigns should be launched for adequate risk communication on the adverse effects of soot, with attention given to gender-sensitive messages.

In [2], it was advised that relevant authorities should develop stringent policies to prevent soot pollution and improve access to appropriate services to address the health effects. Incidence of pathogenic microbes associated with black soot in indoor aerosols of classrooms in Port Harcourt, Rivers state, Nigeria was reported. Six major sources of black soot have been identified; Burning of local "kpo-fire" crude oil for the production of diesel and Kerosene, Smoke from refinery and petrochemical industries, Gas flaring from flow stations of oil companies, Smoke generated from both industrial and domestic, Smoke from the exhaust of vehicles of all types, Burning of vehicle tyres either at animal slaughter abbatoir or for other purposes. Atmospheric black carbon affects the hygroscopicity of cloud condensation nuclei, which in turn, affects atmospheric heating, stability, large-scale circulation, and overall cloud albedo.

II. REVIEWED WORKS

In [3], awareness and Impact of Black Soot on Selected Food Vendors in Port Harcourt, Rivers State, and Nigeria were examined. A simple random sampling technique was used to select 150 respondents from 10 communities in the Port-Harcourt metropolis. Data collected was analyzed using descriptive statistics, Chi-Square statistics, and simple linear regression. The results showed that a significant number (96.7%) of Port Harcourt residents were aware of the presence of black soot. The residents (32.0%) were equally aware of the health dangers of black soot. 85% of the residents were aware of illegal bunkering being the number one cause of black soot. 78% of barbecue food vendors reported decreased patronage due to black soot pollution and the regression results showed that black soot significantly and adversely affects barbecue food vendors in Port Harcourt. They concluded that the black

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soot negatively affects the livelihood of barbecue food vendors in the Port Harcourt metropolis, and recommended that the vendors should take steps to employ hygienic practices to mitigate the effect of black soot on the food they sell and also for the government to tackle illegal oil bunkering as it is the major cause of black soot in the state. An air quality monitoring system with emergency alerts using IoT was developed as in [4-5]. The system used sensitivity sensors to determine the quantity of many small particles within the air such as O_3, SO_2, CO, and objects. The monitored data was processed and transmitted directly to the cloud system using a wireless LAN module in Arduino for access to the cloud service. Results were displayed directly on a web page application provided by the cloud service. In [6], Air Quality Monitoring (AQM) Models Using Different Machine Learning Approaches was developed. Their work concentrated on particulate matter (PM), SO_2, CO, NO, and O_3. The meteorological elements were collected in different locations in the last 5 years, with a time window of 24h, and mapped to the concentration level of pollutants. Machine Learning (ML) algorithms such as Non-Linear Artificial Neural Networks (ANN), Statistical Multilevel Regression, Neuro-Fuzzy, and Deep Learning Long-Short-Term Memory (DL-LSTM) were used to find the current concentration level of pollutants. The results were compared with parameters such as R^2, RMSE, and MAPE. Using these methods, the concentration level of contaminants was predicted with a deviation of R^2 in the range of 0.71–0.89. The results proved that DL-LSTM suits well when compared to the ANN, Neuro-fuzzy, and regression algorithms. A Smart Embedded Framework using Arduino and IoT for Real-Time Noise and Air Pollution Monitoring and Alert system was discussed in [7]. Their work provided a solution for noise and air pollution level monitoring in any area of interest using a wireless embedded computing system. All components in the system like ESP8266, Xmega 2560, sound sensor, dust, gas, humidity, temperature sensor, and Wi-Fi were connected to the Internet of Things (IoT). ThingSpeak environment was used for recording the collected sound and air quality information. Alert is sent to the authorities whenever the pollution exceeds a certain set limit. A low-cost, small-size wireless sensor network (WSN)-based participatory monitoring system was designed and implemented [8]. The system is composed of mobile sensing nodes measuring temperature, humidity, and several pollutants (NO_2, PM1, PM2.5, and PM10). The collected data were sent to a server for analysis and building temperature and air quality maps. To validate its platform, they carried out multiple tests to compare sensor nodes to reference stations and each other. Also, the energy consumption of the nodes under different configurations and the results were satisfactory which showed that the nodes can be used in environmental participatory monitoring. In [9], an Intelligent and Secure Air Quality Monitoring System was developed using a Neural Network (NN) Algorithm and Block-chain. The Internet of Things (IoT) connects and processes data, and low-cost sensors collect the data from the environment. The Indoor Air Quality system consists of temperature, humidity, Carbon dioxide, particulate matter, carbon monoxide, and LPG. The data were collected from five different sensors and the NN decision-making model was used to predict the AQI to prevent harmful situations. The suggested IoT-based smart blockchain technology played a vital role by imparting scalability, privacy, and reliability. An improved air quality and climate control monitoring system using fuzzy logic for enclosed areas was developed as stated in [10]. They built an automated system that manages indoor temperature, humidity, and air quality sensors connected to the Arduino microcontroller using fuzzy logic technique. MQ-135 sensor measures air quality, DHT-11 sensor measures the temperature and humidity of the environment. These sensors transmit their readings to a microcontroller to set the ventilation speed for the indoor environment, which removes harmful gases and maintains acceptable temperature and humidity levels. The system performance showed excellent results in controlling and monitoring air quality, temperature, and humidity compared with a previous design due to an increased range between the minimum and maximum values of the ventilation speed. In [11], the FreeRTOS-Based Air Quality Monitoring System using the Secure Internet of Things was discussed. Arduino Nano with IoT technology was integrated to measure parameters such as CO_2, temperature, humidity, and heat index. MQ135 and DHT22 were used to sense CO_2, temperature, humidity, and heat index respectively. Data was sent periodically to a web server using the ESP8266 Wi-Fi module through secure Hyper Text Transfer Protocols POST protocol. On the back-end side, a web server was employed to receive sensor parameters, and a website application was developed to monitor it remotely. The system was tested to monitor CO_2 in 4 different locations in Pangkal Pinang city, Indonesia. The results showed that the averages of CO_2 concentration in Housing Indo Graha, Morning Market, Dea Lova Park, and Pasir Padi Beach were 411.37 ppm, 485.97 ppm, 416.45 ppm, and 444.43 ppm respectively. Results show that public place i.e. Pasir Padi Beach has higher CO_2 concentration meanwhile public place with organic waste i.e. Morning Market has the highest CO_2 concentration. In [12], IoT-enabled environmental toxicology for air pollution monitoring using AI techniques (ETAPM-AIT) was developed to improve human health. The ETAPM-AIT model includes a set of IoT-based sensor arrays to sense eight pollutants namely NH_3, CO, NO_2, CH_4, CO_2, PM2.5, temperature, and humidity. The sensor array measures the level of the pollutant and transmits it to the cloud server via gateways for the analytic process. The model reports the status of air quality in real-time by using a cloud server and sends an alarm in the presence of hazardous pollutants level in the air. For the classification of air pollutants and determining air quality, the Artificial Algae Algorithm (AAA) based Elman Neural Network (ENN) model was used as a classifier, which predicts the air quality in the forthcoming time stamps. The AAA was applied as a parameter tuning technique to optimally determine the parameter values of the ENN model. Simulation analysis was done to examine the air quality monitoring performance of the ETAPM-AIT model. The results were inspected in 5, 15, 30, and 60 min of duration respectively and the experimental outcome showed an optimal

Edem Donald and Ezeofor Chukwunazo Joseph, "An Intelligent Wearable Real Time based Black Soot Monitoring and Alerting System in Nigeria," *International Research Journal of Advanced Engineering and Science*, Volume 9, Issue 1, pp. 103-108, 2024.

performance of the ETAPM-AIT model over the recent techniques.

In [13], an IoT-based system for air pollution monitoring and prognosis using a hybrid artificial intelligence technique was developed. The air qualification index was developed using Linear Regression, Support Vector Regression, and the Gradient Boosted Decision Tree GBDT Ensembles models over the next 5h and analyzed air qualities using various sensors. Three algorithms of Artificial Intelligence were used to create good forecasting models and a predictive AQI model for 4 distinct gases: carbon dioxide, sulfur dioxide, nitrogen dioxide, and atmospheric particulate matter. The hypothesized artificial intelligence models were evaluated to the Root Mean Squares Error, Mean Squared Error, and Mean absolute error, depending upon the performance measurements, and a lower error value model was chosen. Based on the algorithm of the Artificial Intelligent System, the level of 5 air pollutants like CO2, SO2, NO2, PM 2.5 and PM10 could be predicted immediately by integrating the observed errors. It might be used to detect air quality from a distance in large cities and could assist in lowering the degree of environmental pollution.

III. METHOD

The embedded system was achieved using a top-down design approach which led to splitting the system into hardware and software modules. The Embedded hardware module comprises the input, control, power supply, and output units and was designed using the prototyping method. The software module was developed using agile methodology and a program written to control the behavior of the system using C programming language. The block diagram of the soot monitoring and alerting system is shown in fig. 1.

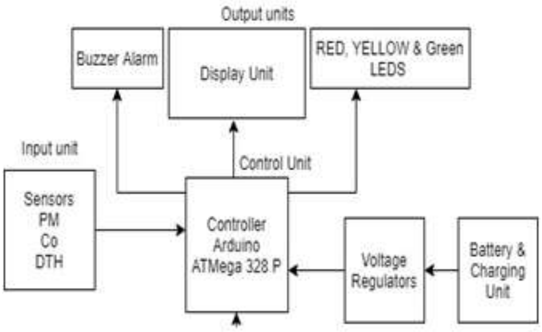

Fig.1. Black Soot monitoring system block diagram

A. *Embedded Hardware Components*

The embedded hardware (fig. 2) consists of power supply, input, control, and output units. The power supply unit provides +5v DC voltage to the system for operation. A 3.7V Li-ion battery with a voltage regulator integrated circuit was used to regulate the required voltage. The input unit measures the quality of the air using a particulate matter sensor (PM), carbon dioxide sensor (MQ-7), humidity and temperature sensor (DTH22) and sends the measurements to the controller for processing. The control unit uses Arduino Atmega 328P to process and analyze the measured parameters and sends the results to the display unit for display to the user. The display unit and Liquid crystal display (LCD) show the quantity of these parameters as detected. Light-emitting diodes are used to notify the user of the quantity of soot in the air via different colors and displays. The wearable device has an inbuilt alarm to alert the user of the presence of soot and its health implications.

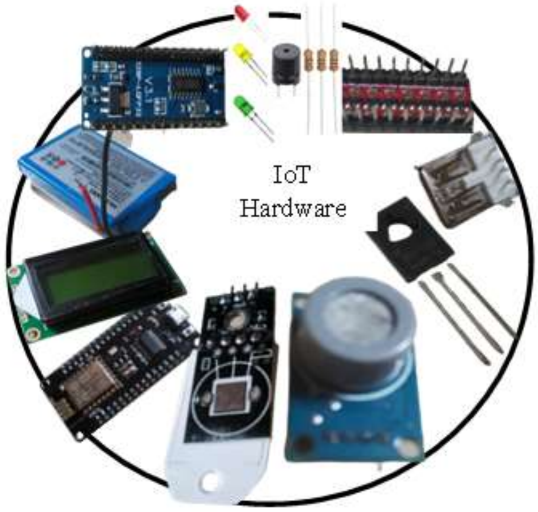

Fig. 2 The embedded hardware components

B. *System Algorithm and Flow Chart*

The embedded C programming language is used to write a series of scripts that the microcontroller uses to process, control, and display information to the user. The Algorithm with flow chart (fig. 3) developed for the control system is as follows:

Step1. Start
Step 2: Initialize all variables
Step 3: Read battery Voltage
Step 4: Read from the PM sensor
Step 5: Compute the density of soot particles in the Air
Step 6: Read Temperature and Humidity
Step 7: Compare and evaluate the density of Soot particles
Step 8: If the density of soot detected is less than 100, activate the green LED to indicate Air Quality ok and activate the buzzer to beep once, then go to step 9
Step 9: if the density of soot detected is greater than 100 but less than 150, activate the blue LED to indicate Air Quality Unsafe and activate the buzzer to beep twice, then go to step 10
Step 10: If the density of soot detected is greater than 150 but less than 250, activate Red LED to indicate Air Quality Toxic and activate the buzzer to beep thrice, then go to step 11
Step 11: Display the measured variable.
Step 12: Go back to step three

C. *System Operation and Circuit Diagram*

When the user switches ON the two-way switch attached to the device, the 3.7v Li-ion battery source is regulated to +5V DC that powers the microcontroller, Liquid crystal display (LCD), Wi-Fi module, and all the sensors. The microcontroller initiates a command through the written program to read the measured values from PM, DTH, and CO2 sensors.

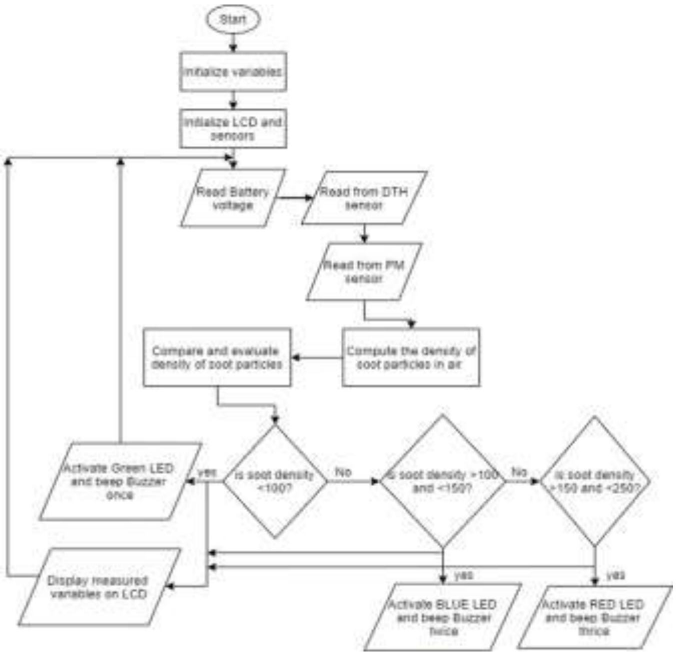

Fig.3: Flow chart of the Soot detection and alarming system

The measured values are evaluated to trigger the RED, BLUE, and GREEN light-emitting diodes and sound alarms. The measured value from the soot sensor is compared within the range of 0-99 set point and triggers a Green light emitting diode and sound alarm once if the value is less than 100, indicating that the soot level on air is NORMAL and good for human consumption. Blue Light emitting diode is triggered and the alarm beeps twice when the soot level is more the 99 but less than 150 values, indicating that the environment is polluted with an average little soot. Finally, the Red LED is activated and the alarm beeps thrice when the soot value rises more than 149 and less than 250, indicating the presence of plenty of soot in the environment which is not safe and good for human consumption.

In each time interval, the display is made to show the values of soot density, temperature, humidity, and battery level. The process is repeated and the LED keeps changing with different alarm beeps depending on the ratios of the soot levels measured. The circuit diagram of the soot detection and alarm system is shown in fig. 4.

D. System Prototype

The system was constructed using two separate materials namely plastic and plywood materials. The upper material is plastic and the bottom soft plywood is neatly cut and covered with brown binding paper and blue. The length measured is 10cm; breathe 7.5cm and the height is 6cm. Battery, microcontroller, and wires were arranged inside the small rectangular box constructed of soft play wood material as shown in fig. 5a. The sensors, USB port, switch, LEDs, and buzzer wer strictly arranged inside the top plastic box while holes were made to bring out the switch, LCD, USB port, soot, carbon monoxide, temperature, and humidity sensors outside the box. The system prototype is shown in fig. 5b.

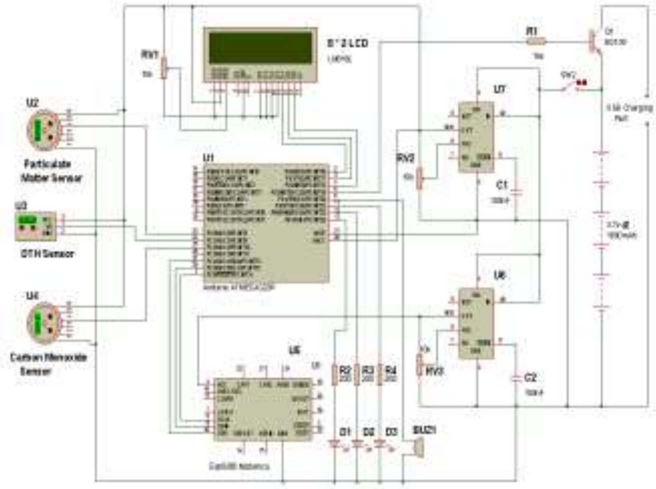

Fig. 4: Circuit diagram of the soot detection System

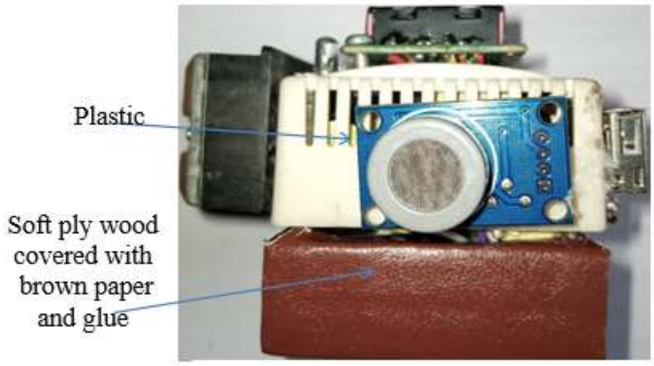

Fig. 5a: Back view of the wearable soot device

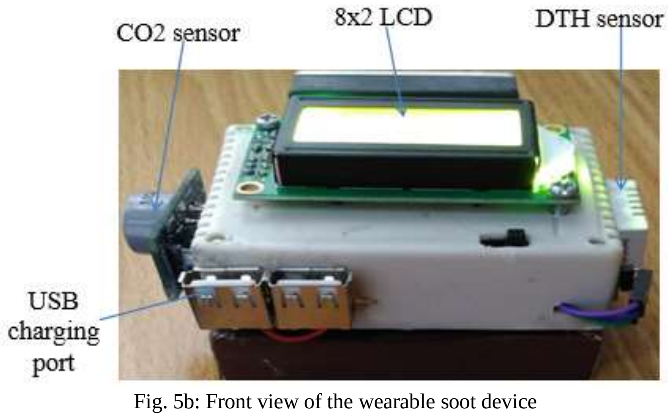

Fig. 5b: Front view of the wearable soot device

IV. Results Obtained

A. System Test

The first test conducted using the soot monitoring device was across some parts of Port Harcourt city in Rivers State, Nigeria. It was discovered that some parts that had no fire-burning activities recorded a soot level of 6.11mg/L and Carbon content of 2192mg/L, and the system activated green LED ON and displayed soot very low on the device with air quality fresh as shown in fig. 6. The system sounded alarm once with constant display.

Edem Donald and Ezeofor Chukwunazo Joseph, "An Intelligent Wearable Real Time based Black Soot Monitoring and Alerting System in Nigeria," *International Research Journal of Advanced Engineering and Science*, Volume 9, Issue 1, pp. 103-108, 2024.

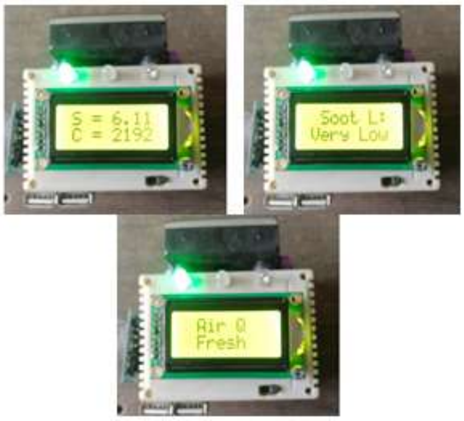

Fig. 6: First test Soot device displays Air Quality Fresh

The second test conducted was also in some parts of the State that recorded brief burning activities. There was an increase in soot (28.5mg/L) and carbon (2492mg/L) detection levels in the areas and the system recorded the changes and sounded the alarm twice to alert the user of the unsafe environment with a blue LED light ON as shown in fig. 7.

Fig. 7: Second test soot device detected unsafe environment

In the final areas visited, a lot of activities were done there and the system recorded a high level of soot and carbon detections and sounded an alarm three times with a red LED light ON, which indicates the environment, is highly toxic and needs to be evacuated. The results are shown in fig. 8.

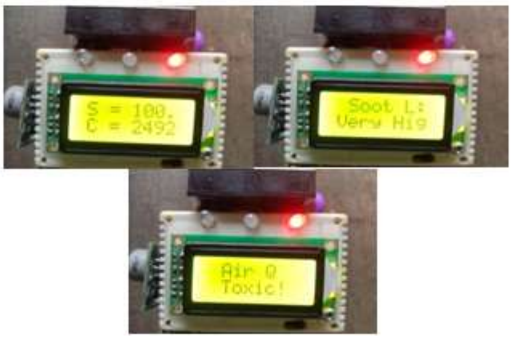

Fig. 8: Final test displays air quality toxic

In summary, the detected soot level of 28mg/L indicates an unsafe level and the system displays it on the screen while a beeping sound was also generated. It was observed that an atmospheric carbon content of about 2192mg/L was recorded when the soot level was low (6.11mg/L). Surprisingly though, this value rose to 9464mg/L when a moderate or lower level of soot was detected (28.5mg/L). This surprising increase in carbon content with a reduced soot level indicates that the carbon content in the air does not increase in proportion to the amount of soot present in the same air space. It was noticed also that the system detected a soot level of 100 mg/l which is a rather high and hence dangerous level. The system responded to this high level of detected soot by generating a beeping warning sound from the built-in sound buzzer while displaying a message on the screen that the air quality in that area is toxic. The summary of the test conducted is shown in table 1.

TABLE 1: Summary of the test conducted in various parts of the Rivers State, Nigeria

S/N	Soot level mg/L	Carbon Level	System Remark	Air Quality	Display LEDs			No of Buzzer Sounds
					Green	Blue	Red	
1	6.11	2192	Soot Level very low	Fresh	On	Off	Off	Single Beep
2	28.5	2492	Soot Level low	Unsafe	Off	On	Off	Double Beep
3	100.0	9464	Soot Level High	Toxic	Off	Off	On	Triple Beep

V. CONCLUSION

The wearable real-time-based soot monitoring and alerting system has been designed and implemented. The system would go a long way to help users monitor the black soot on the air in their environments and alert them of its health implications through alarm for necessary action. This would avert various diseases being recorded daily across the State, caused by the inhaled soot found on the food exposed in the market. The device is designed to be worn on a human hand and has no health effects. The system is made simple and cost-effective for both the poor and the rich. With this device, anybody working in an exposed and dangerous zone would rest assured of the system monitoring and reporting any element of black soot in the environment. To further enhance the system, Artificial intelligence can be applied to develop model that will perform real time prediction. The user can view the trends via any IoT App platform to check mate the locations with more black Soot and avoid the areas.

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