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Air Quality Monitoring and Controlling System Using Dust Sensor

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Ultrafine particles smaller than 2.5 μm in diameter are mainly produced from burning fossil fuel and aeolian dust. They deteriorate air quality and health as they can accumulate in the distal airways and gas-exchange regions of the lungs. Thus, it is necessary to monitor the concentration of ultrafine particles in the air accurately and continuously. Therefore, we developed an automatic particulate matter monitoring system with a dust sensor, actuators, and a microcontroller. The system is connected online to the web to monitor the concentration in real time and provide an alert when the concentration exceeds a safe range.

1. Introduction

The cement and quarrying industries are some of the most polluting industries according to the Central Pollution Control Board in India.(1,2) Fine dust emitted from factories and quarries worsens the quality of air, water, soil, land, and vegetation, and affects agriculture and plant biodiversity.(2) Such a negative impact causes habitat destruction and plant biodiversity reduction. Plants near cement factories or quarrying sites even can be extinguished. Dust from the desert also harms the air quality in its vicinity.(3) In such areas, it is essential to monitor air quality in real time to prevent any damage caused by fine dust.

Windblown dust from such areas contains high concentrations of particulate matter smaller than 2.5 μm in diameter (PM2.5).(4) By measuring the amounts of PM 10, 2.5, and 1.0 in windblown dust, the relationship between the particulate matter in the air and meteorological factors can be investigated.(5) Air pressure affects the transport and accumulation of particulate matter in the air while winds disperse particulate matter in the air but transport it at the same

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time. Precipitation accelerates the deposition of particulate matter on land and inhibits surface dust transport.

Secondary PM 2.5 includes nitrous oxides, sulfur oxides, ammonium, and volatile organic carbons, which can damage human health significantly. When secondary PM2.5 penetrates the lung, it irritates and corrodes the alveolar wall, and consequently impairs lung function. Exposure to PM2.5 increases the susceptibility of human tissue to various pathogens and the risk of respiratory infections.(6–8) PM2.5 poses a public health hazard even at a very low concentration.(9,10) Microorganisms in PM2.5 also cause mononuclear inflammation or disrupt the microbial balance, contributing to the onset and progression of chronic obstructive pulmonary disease.(11) PM2.5 can induce pathogenesis in lung cancer and chronic airway inflammatory diseases.(12,13) To reduce the concentration of PM2.5 indoors, a transparent air filter is recommended as it has a filtering efficiency of 98.69% for PM2.5.(14) By using air purifiers, the health problems caused by PM2.5 can be reduced by 42.09%.(15) The PM2.5 concentration needs to be maintained at less than 10 $\mu g/m^3$ using a prefilter system to prevent any health problems.(16)

Along with air purifiers, it is also essential to monitor the concentration of PM2.5 to avoid its potential harm. To monitor the concentration, an indoor monitoring system was developed using a Zigbee sensor and an Arduino microcontroller.(17,18) Arroyo *et al.* designed an air quality monitoring system with a distributed sensor network using Zigbee communication.(19) At present, most PM2.5 monitoring systems adopt Zigbee for network communication. However, Zigbee has a limited communication range, a low stability, and a high cost of maintenance.(20) Instead of the Zigbee with such disadvantages, a reliable microcontroller with built-in Wi-Fi communication needs to be used in the monitoring system.

In this study, we constructed an automatic particulate matter (PM2.5) detection system (APMDS) equipped with a dust sensor, warning lights, an alarm, and an air cleaner. The system is connected to the Wi-Fi network. It displays the concentration of PM2.5 in the air and transmits the data through a microcontroller with a built-in Wi-Fi module. The system can be used at home or in public areas to monitor the air quality and prepare people for worsening air quality.

2. System Structure

The structure of APMDS is shown in Fig. 1. The dust sensor is adopted to measure the concentration of PM2.5. When the concentration is higher than a preset threshold, the wall-mounted air cleaner equipped with a fan and a filter begins to operate. The air quality is indicated by a green, yellow, or red LED light in accordance with the measured concentration. A microcontroller with a WiFi module transmits the measured data. The wiring diagram for APMDS is depicted in Fig. 2. A dust sensor, LED lights, an alarm, and an actuator of the air cleaner are connected to the microcontroller. An Internet protocol camera (IP camera) is installed on the wall. The microcontroller is programmed by JavaScript and is connected to a web server.

The control logic of APMDS is shown in Fig. 3. The PM2.5 concentration of 100 ppm is set as the threshold value, and the upper limit of the concentration is set as 200 ppm. The

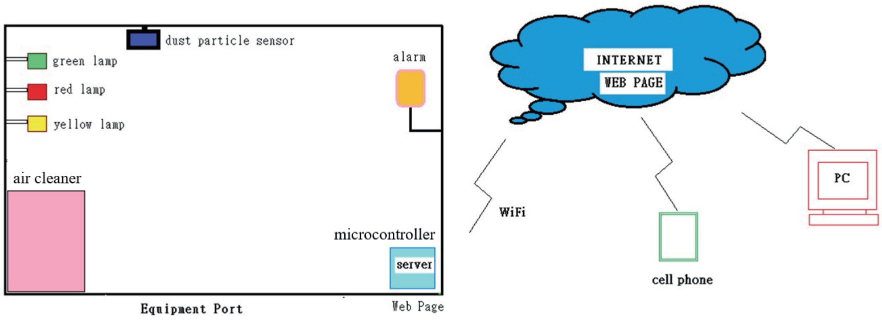

Fig. 1. (Color online) Web-based air monitoring and controlling system (APMDS).

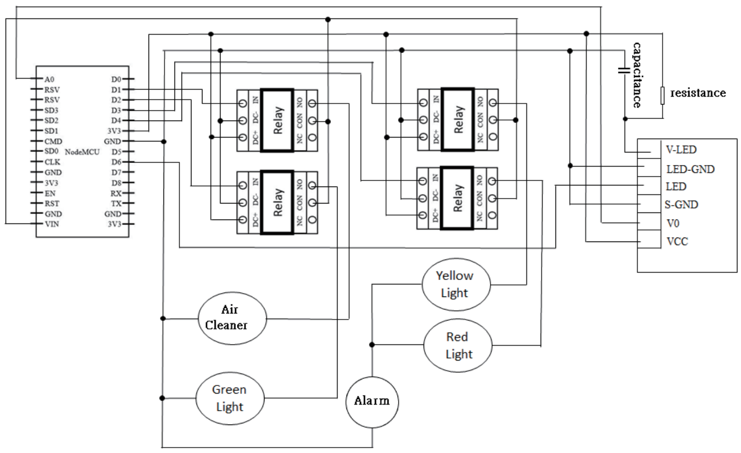

Fig. 2. Wiring diagram of APMDS.

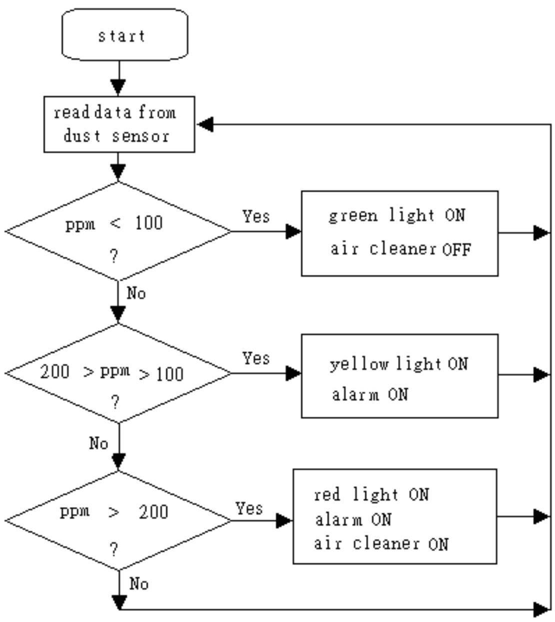

Fig. 3. Control logic for APMDS in automatic mode.

concentration is continuously measured and displayed. The green light turns on when the concentration is lower than 100 ppm. The yellow light and the air cleaner turn on when the measured concentration is between 100 and 200 ppm. The red light turns on, indicating that the air cleaner begins to operate when the concentration is higher than 200 ppm. In monitoring the concentration, an automatic or manual mode can be selected. The measured concentration and captured images are displayed on the screen.

3. Data Transmission

The embedded WiFi module in the microcontroller connects APMDS to the Internet via Wi-Fi networks. A web page was created using JavaScript (Fig. 4). The user can log in to the web page remotely to view the current concentration and pictures of the measuring site. The interface of the web page is programmed using the C# program (Fig. 5).

On the interface, the user can monitor the concentration of PM2.5 and measuring sites and control the system (Fig. 6). The air cleaner, the IP camera, LED lights, and the alarm can be operated automatically or manually.

```
int lsout;
int ledPin = LED_BUILTIN;
int fout=5;
int L_G=4;
int L_Y=0;
int L_R=2;
unsigned long timetest;
bool value = HIGH;
int op_mode=0;
int dustPin=A0;
float dustVal=0;
int ledPower=12;
int delayTime=280;
int delayTime2=40;
float offTime=9680;
WiFiServer server(80);
void air(){
  digitalWrite(ledPower,LOW);
  delayMicroseconds(delayTime);
  dustVal=analogRead(dustPin);
  delayMicroseconds(delayTime2);
  digitalWrite(ledPower,HIGH);
  delayMicroseconds(offTime);
  //delay(500);
  //Serial.print(dustVal);
  //Serial.print(",");
  //if (dustVal>36.455)
  //Serial.println((float(dustVal/1024)-0.0356)*120000*0.035);
}
void setup() {
  Serial.begin(115200);
```

Fig. 4. (Color online) Abstract of program for microcontroller of APMDS.

Fig. 5. (Color online) Abstract of C# program for interface.

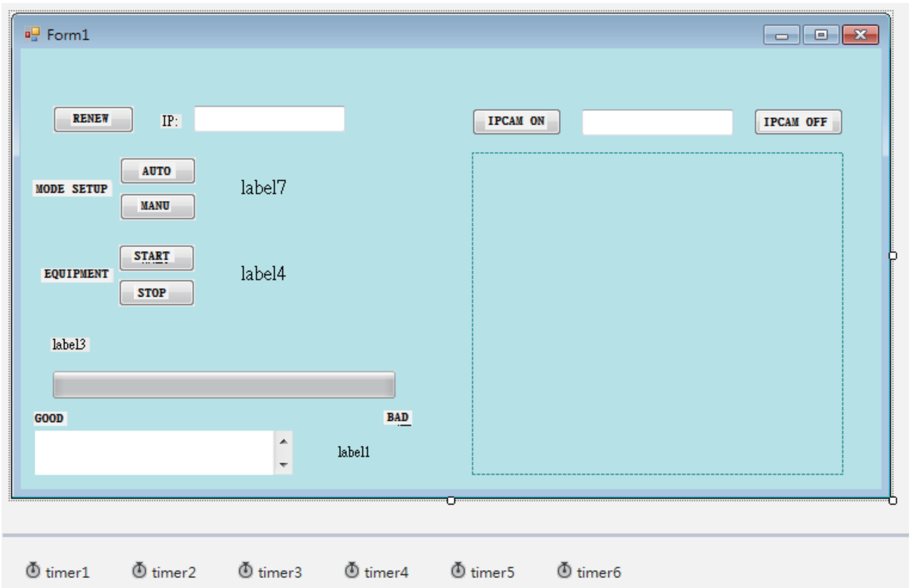

Fig. 6. (Color online) Interface of APMDS.

6. Results and Discussion

APMDS was tested in the automatic mode first. The green light turned on when the measured concentration was lower than 100 ppm (Fig. 7). The yellow light and alarm turned on when the measured concentration was in the range of 100 to 200 ppm (Fig. 8). The red light, alarm, and air cleaner began to operate when the measured concentration was higher than the set threshold of 200 ppm (Fig. 9).

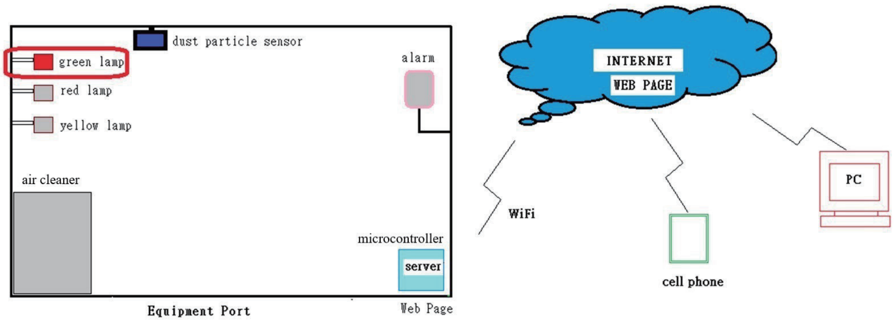

Fig. 7. (Color online) The green light turns on when the measured concentration is within the safety range of lower than 100 ppm.

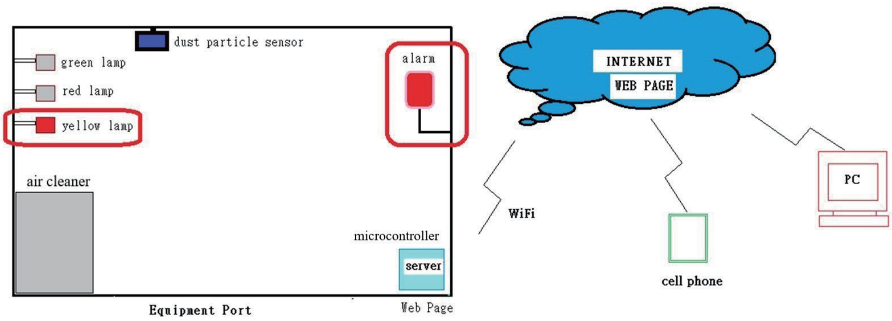

Fig. 8. (Color online) The yellow light and alarm turn on when the measured concentration is between 100 and 200 ppm.

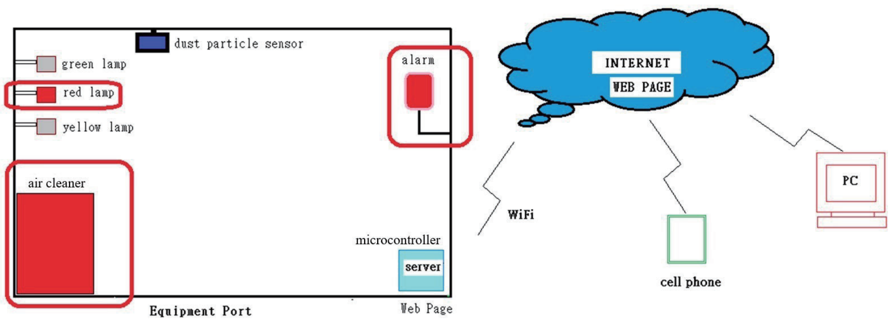

Fig. 9. (Color online) The red light, alarm, and air cleaner turn on when the measured concentration is higher than 200 ppm.

The microcontroller of APMDS is linked to the web server, and the web page is available on the Internet. A computer or a mobile device can be used to access the web page. Users can remotely control APMDS in the automatic or manual mode. The concentration of PM2.5 is monitored in real time, and measured values are displayed on the interface of APMDS as shown in Fig. 10. For data transmission, Wi-Fi is used to improve the limitations of the Zigbee module used widely in similar systems.

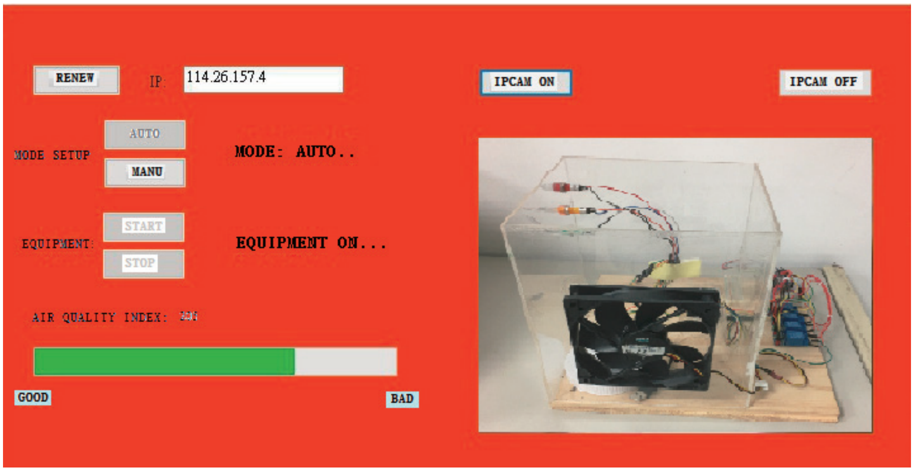

Fig. 10. (Color online) Interface of APMDS under operation.

5. Conclusions

APMDS was developed to reduce the impact of PM2.5 on human health. APMDS is a web-based air quality monitoring system to monitor and control indoor air quality. One dust sensor and five actuators are included in APMDS. A microcontroller controls the system and connects it to the Internet for remote control and data transmission. Users are allowed to monitor the air quality and control APMDS via the web page using a computer or a mobile device. An IP camera is included to view the monitoring site. APMDS can be controlled automatically or manually. APMDS displays the concentration of PM2.5 in the air and its green, yellow, and red LED lights show the level of the concentration so that users can be cautious of worsening air quality and control APMDS if necessary.

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