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A Low-cost, Portable, and Wireless Environmental Pollution Exposure Detection Device with a Simple Arduino-based System

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Air pollution causes poor air quality and visibility reduction, which will affect traffic safety and life quality. Progressive technologies provide people a comfortable life, but also bring some kind of pollution, and endanger human health. The low air quality caused by air pollution and related diseases caused by ultraviolet light are all major factors related to the environment and have an impact on long-term health. In particular, they impact persons in hospitals, schools, factories, and other living spaces. The related applications of portable devices are no longer confined to Internet of Things (IoT) services. Many providers are committed to provide various applications and bring more commercial possibilities with portable devices. With new kinds of products, more emphasis has been placed on consumer experience and human-related applications. This research is focused on developing a portable wireless environmental and medical assistance sensing system. It is a sensing system that combines airborne particle, temperature, humidity, and UV measurements, and wireless function. It can be placed in any workplace or home environment for real-time measurement and used with IoT. It can upload data to remote servers, and one can check them using laptops, computers, and smart phones, with the environmental warning light indicator being active to protect oneself.

1. Introduction

Life is inseparable from products such as clothing, food, detergents, paint, furniture, toys, cosmetics, pharmaceuticals, and electronic devices. During their production, use, and disposal, such products will continue to release harmful substances, some of which are carcinogenic or may cause deformities in babies. They will also accumulate in the food chain. Poisonous and harmful substances pose potential hazards to people, organisms, or the environment. These dangers include the following:(1–5)

1. Persistence—they will stay in the natural environment for a long time, not easily decomposed by biodegradation or other methods;
2. Bioaccumulation—they can accumulate in the body or even accumulate in the food chain;

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3. Toxicity and carcinogenicity—they can cause cancer;
4. Gene mutagenicity—they can cause genetic variation and teratogenesis in the body;
5. Reproductive toxicity—they are toxic to the reproductive system;
6. Interfere with endocrine function—they can alter the hormonal system and interfere with endocrine function, even if the dose is extremely low;
7. Neurotoxicity—they are poisonous to the nervous system.

Figure 1 shows the sizes of particulate matter (PM), especially PM10 and PM2.5, which are toxic and hazardous substances. These poisonous and harmful substances can come from everywhere through water, air, soil, and living organisms.

Human beings are usually exposed to the hazards of air and environmental pollution. They do not feel that they have been exposed for a long time to invisible hazards. Exposure to high concentrations of suspended particulates for a long time is extremely harmful to the human body. Figure 2 shows the systems of the human body. Therefore, we designed a system for the low-cost and wireless measurement of PM2.5 aerosol, and carried out real-time monitoring to upload the data online, allowing researchers to have access to the information at any time. However, they also should think about how to improve and address the current problems.[6–10] Changing the status quo should not lead to a serious increase in pollution, and we must not only consider the survival of the present generation, but also of the next generation.

2. Materials and Methods

The impacts of many hazardous chemicals cannot be eliminated. Once toxic and hazardous substances are released into the environment, it is difficult or even impossible to control their effects. If hazardous chemicals are discharged through industrial wastewater, even if they are treated by ordinary sewage treatment plants, a large number of toxic and hazardous substances cannot be eliminated. In this study, we propose a wireless and portable integrated device with the combination of an Arduino UNO/Nano V3 microprocessor board, a Sharp DN7C3CA006

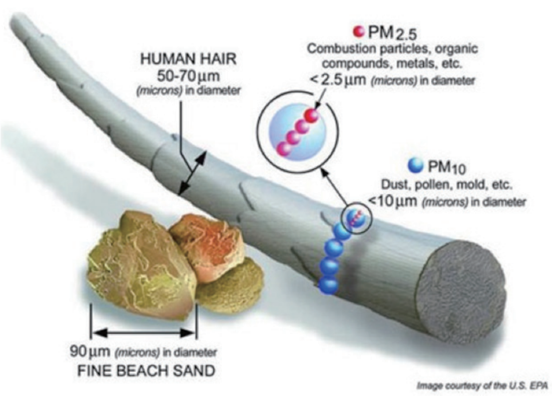

Fig. 1. (Color online) Sizes of PM, especially PM10 and PM2.5. (Available at https://www.epa.gov/pm-pollution/particulate-matter-pm-basics)

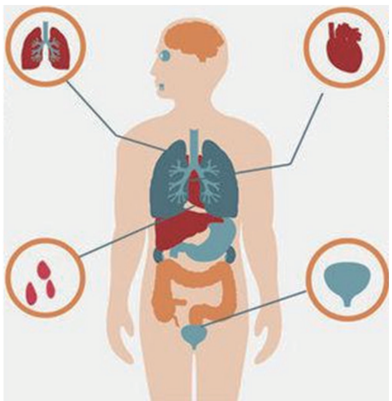

Fig. 2. (Color online) Systems of the human body. (Available at http://www.how01.com/post_vW54jzZLAJ7rp.html)

optical dust monitor, a DHT22 humidity/temperature sensor, a UV sensor, an ESP8266 Wi-Fi module, an LCD module, and a 3.7 V battery.

2.1 Arduino-based development kit

The Arduino UNO [Fig. 3(a)] unit in this experiment is used as a tool for a development platform. The board model is UNO R3. It is an 8-bit microprocessor using ATMega328 and includes the central processing unit (CPU), built-in memory, analog-digital signal converters, and peripheral control devices. ATMega328 is also known as a single-chip microcomputer or microcontroller; the pin assignments D0~D13 are digital inputs and outputs, and the symbol "~" indicates pulse width modulation (PWM), which is an analog signal output. A0–A5 are analog input ports and can also be used as the digital pins D14–D19.

2.2 Proposed measurement system

The model number of the suspended particle sensor developed by Sharp Electronics Co., Ltd. [Fig. 3(b)] is GP2Y1051AU0F. The main principle is the application of a photodetector (PD) and a light-emitting diode (LED). As input conditions of the LED terminal, the LED drive conditions indicated in the chart of specified electro-optical characteristics are applied. When it is impossible to apply those conditions, the recommended input conditions should be within the specified ones. When the LED is driven under the condition beyond the specifiied one, the characteristics of the device will be affected. The intersection of the PD and LED is the main basis for sensing, and the photon signal (photon) can be converted into an electronic signal (electron) and sent back to the microcontroller unit (MCU) through the amplifier circuit for operation. The universal asynchronous receiver/transmitter (UART) serves as a signal output. The pins

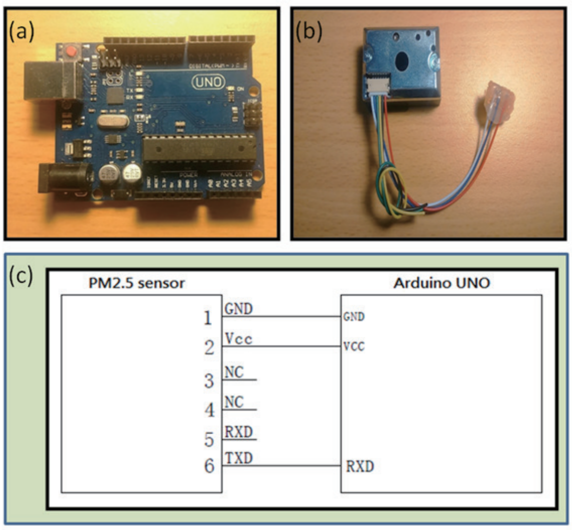

Fig. 3. (Color online) Arduino-based development kit with a suspended particle sensor developed by Sharp Electronics Co., Ltd.

from top to bottom are GND, VCC voltage, NC empty, NC empty, RXD, TXD, and TXD, which are connected to the pin of the Arduino UNO/Nano board [Fig. 3(c)].

Figure 4 shows the function block of this system. The dust sensor and DHT22 transfer the PM2.5 and temperature/humidity data to the Arduino Uno/Nano board, which are shown on the display (LCD5110). The data are sent to the ThingSpeak Internet of Things (IoT) website via the wireless module (ESP8266).

2.3 System verification

The photon signal can be converted into an electronic signal and sent back to the MCU through the amplifier circuit for operation. The UART serves as a signal output. Figure 5 shows the schematic of this system. Figure 6 shows the data and display on the system. Figure 7 shows the serial port data displayed.

3. Results and Discussion

In this study, we proposed a wireless and portable integrated system. Table 1 shows the BOM list of this system. Figure 8 shows the data shown on the PC/mobile app by ThingSpeak.

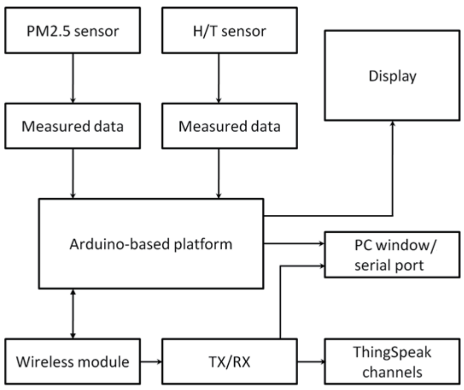

Fig. 4. Function block of this system.

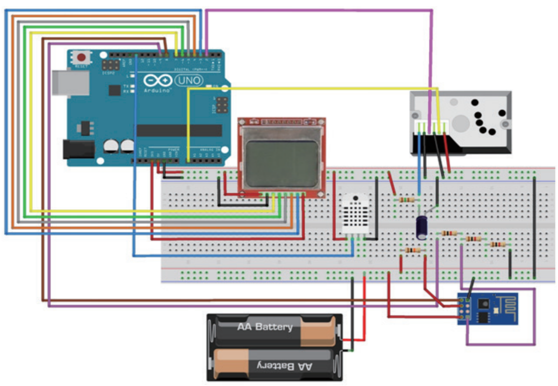

Fig. 5. (Color online) Schematic of this system.

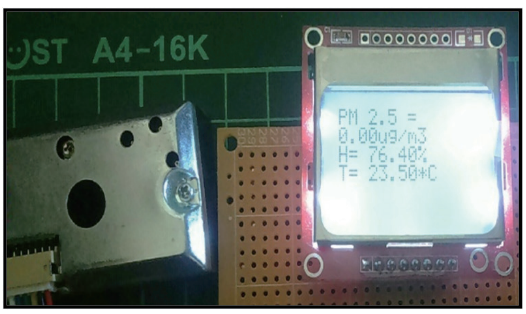

Fig. 6. (Color online) Display on the system.

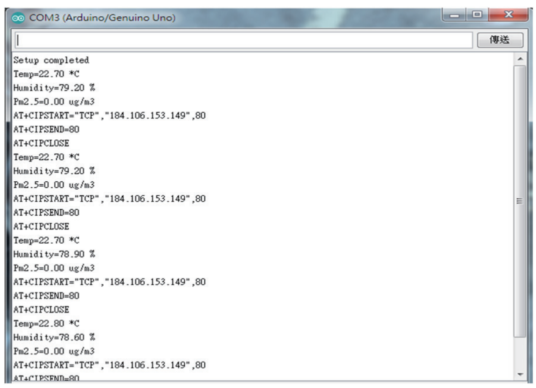

Fig. 7. (Color online) Serial port data display.

Table 1
BOM list of this system ($USD).

Item	Type No.	Q'ty	Cost
MCU system	Arduino UNO/Nano	1	<$8
Wi-Fi module	ESP8266	1	<$5
Dust sensor	GP2Y1051AU0F	1	<$12
Temperature and humidity sensor	DHT22	1	<$3
Display module	LCD5110	1	<$10
Power module	NORMAL	1	<$7
Total			<$45

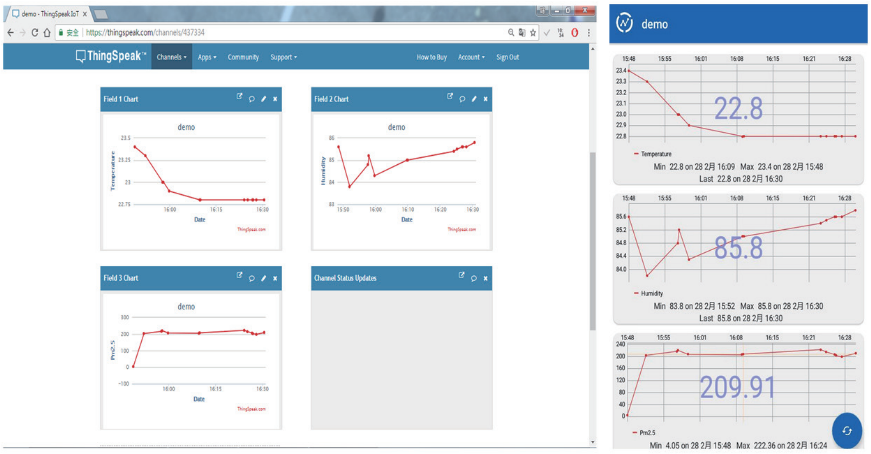

Fig. 8. (Color online) Data shown on PC/mobile app using ThingSpeak. (Note: ThingSpeak is an application to monitor cloud data.)

(Note: ThingSpeak is an application to monitor cloud data) The indoor and outdoor data measured for two days showed that the average AQIs were about 66.34 μg/m^3 on May 30, 2018 and 64.78 μg/m^3 on May 31, 2018. A comparison between the PM2.5 and AQI showed that their changes caused by environmental factors are relatively stable. During the three-minute outdoor walk between May 30 and May 31, the observed AQI suddenly increased. Afterwards, the data gradually returned to a stable state, which was inferred to be caused by the inter-air turbulence between the walks. There is no significant change from the overall environment, so the indoor AQI will not change owing to air conditioning or indoor circulation.

According to the results of the existing development system, there are precedents for the successful uploading of temperature and humidity data, representing the foundation for wireless applications, and the LCD technology can be combined with instant observation and other functions. The relationship between PM2.5 and AQI values observed for four days on June 11th, 12th, 14th, and 17th (Figs. 9–12), R^2 (R-squared) = 0.1368 (Fig. 13), showed that the relevance is small. (The definition of R-squared is fairly straight-forward; it is the percentage of the response variable variation that is explained by a linear model. R-squared = Explained variation/Total variation, the higher the R-squared, the better the model fits your data.)

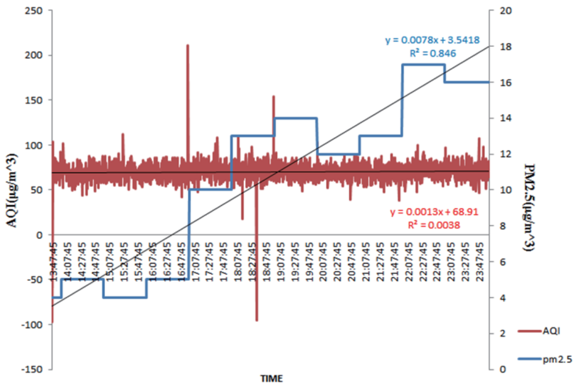

Fig. 9. (Color online) Comparison of 6/11 PM2.5 data and AQI.

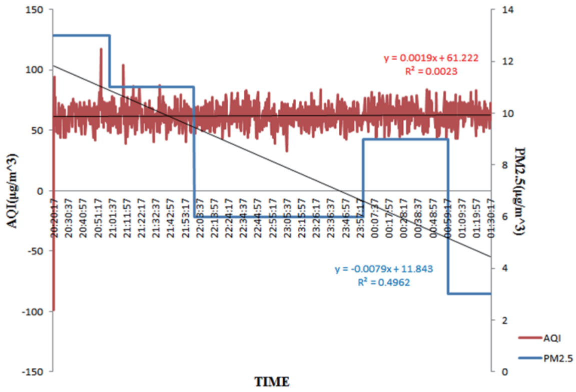

Fig. 10. (Color online) Comparison of 6/12 PM2.5 data and AQI.

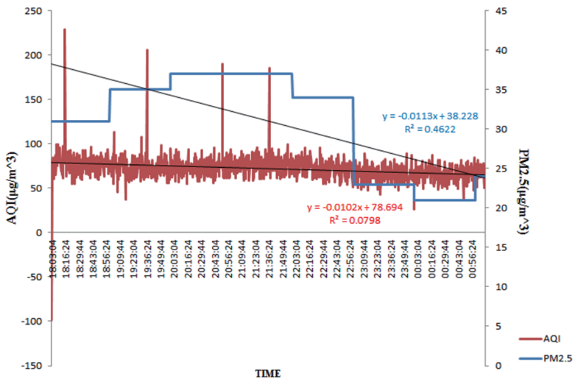

Fig. 11. (Color online) Comparison of 6/14 PM2.5 data and AQI.

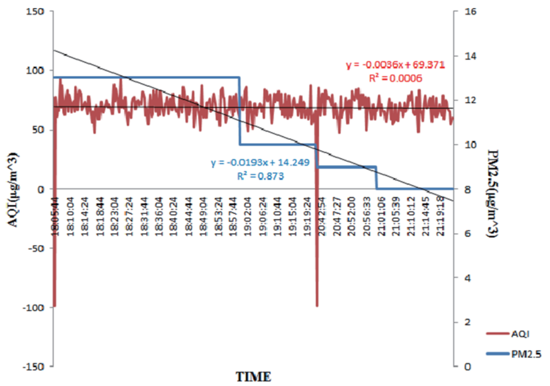

Fig. 12. (Color online) Comparison of 6/17 PM2.5 data and AQI.

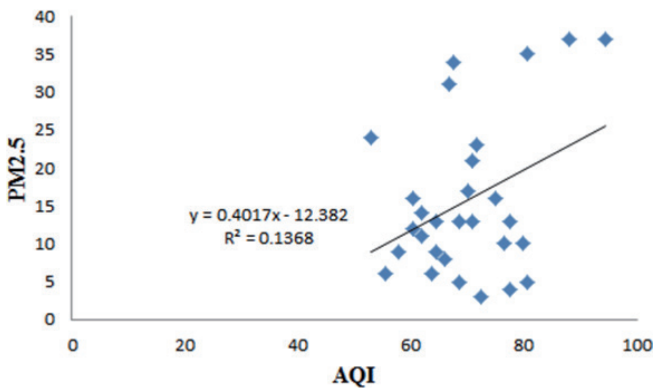

Fig. 13. (Color online) PM2.5 and AQI data relation.

4. Conclusions

In the future, a variety of biomedical sensor modules can be used in combination to develop portable devices, such as UV sensing devices with Bluetooth technology, in conjunction with mobile phones. In addition, Arduino UNO can be replaced with existing device modules.

Arduino Nano, which makes the size of whole module smaller, can be combined with a wearable device. Therefore, it is possible to realize accurate data measurements in the future to improve data precision using a new algorithm.

After the completion of system development, multiple stations can be added and combined with measurements in major hospitals, and the data can be compared and collated uniformly. This allows the unit to assess the state of the environment in real time and assess the status of the patient. As for the future trend, PM2.5 has become one of the issues of concern to the Chinese people. Therefore, after the system is developed, it is expected that large companies will jointly develop technologies for the mass production of this system.

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