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Development of a Healthy Workplace Monitoring System using IoT Technology

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Abstract
Chronic respiratory symptoms such as long-lasting cough, wheezing, shortness of breath, and chest pain are symptoms of respiratory problems mainly developed due to occupational exposures. Occupational disease is primarily produced by the air of the factories polluted by poisonous gases, fumes and dust emanating from the manufacturing processes. An unhealthy environment will affect the worker's productivity, leading to low productivity in the workplace. In this work, we have developed a monitoring system to monitor air pollution in a workspace. The developed system is designed with a smart alert system that can help workspace management to receive a notification when the workspace is in bad air pollution conditions. The system is developed using the Rapid Application Development model by considering three-layer Internet-of-Things Architecture. The system is equipped with sensors and Arduino in the device layer, Wi-Fi in the network layer, and a cloud platform in the application layer. The developed prototype is verified through functional tests, gas detection and cloud integration.

Keywords:
Healthy Workplace, IoT, Smart Monitoring

Introduction

Chronic respiratory diseases represent a public health challenge in both industrialized and developing countries because of their health and economic impacts (Sentilselvan et al., 2020). In a related study, it has been reported that industry workers, who are directly exposed to the dust for a longer duration, suffer from more shortness of breath than workers who take precautionary measures (Rahmani et al., 2018).

Most of the the industrial and factories are located in the same area and can be considered a polluted area. An occupational disease is mainly produced by the air of the factories polluted by poisonous gases, fumes and dust emanating from the manufacturing processes (Modi, 2015). Bad air quality level will cause resiporatory diseases among the workes, leads to worker sickness and production loss. Thus, it is necessary to monitor the air quality level in the factories for safety and to ensure the environment is healthy and free from pollutants. According to Occupational Safety and Health Act 1994, every employer and organization should ensure a healthy and safe work environment for employees (Abas, 2020).

On the other hand, Internet-of-Things (IoT) technology is one of the main pillars used in various applications t provide automation and smart application. The IoT system is developed based on the three-layer architecture: the device layer, network layer and application layer (Tomas, 2022).

The aim of building this project is to solve the problem encountered, which is to provide a healthy air- condition wrking environment to the worker. The proposed monitoring system will help the worker to detect and monitor the workplace's air quality level particularly in factories. This monitoring system will analyze the air quality and send notification to monitoring staff when the air quality level reach a certain level. Since the system applies IoT technology, the monitoring can be done from anywhere and fast action can be taken to solve the bad air quality level from 24-hours notication method. This will provide a better environment for the worker and increase company's prodcutivity since numbers of sicks workers can be reduced.

Literature Review

Air pollution is a chemical or particulate matter or biological agent that changes the natural characteristics of the atmosphere (Chang, 2019). There are six major air pollutants which include particle pollution, ground-level ozone, carbon monoxide, sulfur dioxide, nitrogen oxide and lead (World Health Organization, 2018). This pollutant can harm the human health and the environment. Air pollution can cause some diseases such as asthma, lung cancer, autism, fetal growth and low birth weight. Sulphur dioxide is produced from the burning of fossil fuels and smelting of mineral ores that contain sulphur. Exposure to the particle sulphur dioxide can cause skin and lung diseases. The sulphur dioxide concentration of 500 μg/m3 should not be exceeded over average periods of 10 minutes duration (World Health Organization, 2018). Long-term exposure to nitrogen oxide can cause headaches, chest pain, fever and bronchospasm. The guideline value that is set by WHO is 40 μg/m3 to protect the worker from the health effects of gaseous. Carbon Monoxide can cause headaches, dizziness, nausea, and vomiting. The worker of the factory is highly exposed to pollution. According to the Department of Occupational Safety and Health, the Industry Code of Practice has been drawn to ensure that the worker and the occupants are protected from poor air quality, which can affect their health and productivity.

A healthy workplace is one where employees and managers collaborate to continually improve the health, safety and well-being of employees (World Health Organization, 2018). The environment of the factory can affect the worker's health and productivity. A factory can be a dangerous place for the worker as it can cause illness and injured if security precaution has not been taken. Working in a factory makes the worker exposed to different types of health hazards. Most of these operations are characterized by the emission of greenhouse gases (GHG) and other gaseous pollutants such as nitrogen oxide (NOx), sulphur oxide (SOx), carbon monoxide (CO) and particular matter (Zakaria, 2018). The health effects of occupational exposure to selected air pollutants at the workplace can cause more than 86000 deaths a year. Workers exposed to air pollution at their workplace should have medical surveillance, including pre-placement, periodic and final medical examination and test to identify any pre-existing health conditions that can worsen as a result of exposure to air pollution, as well as to determine as early as possible any health effects of occupational exposure and to take measures to prevent disease and disability (World Health Organization, 2018).

Many researches have been conducted to measure air quality and air pollution using Internet of Things (IoT) technology. In (Okokpujie et al., 2018), an environmental monitoring system was proposed. This project utilizes Arduino Uno, MQ 135 and LCD Screen. This project used the MQ135 sensor, which is the air quality sensor. The collected data will first be displayed on the LCD screen and sent to the Wi-Fi module. Wi-Fi module is configured to transfer the measured data as an application on a remote server called "Thing speak". Thing Speak is an open source which provides access to a broad range of embedded devices and web services.

In (Abraham & Li, 2014), the project used Arduino, X Bee modules and Microsensors. The sensor has been integrated into the sensor shield. The mesh networking capability uses a commercial off-the-shelf ZigBee module. This module will greatly simplify. This project has used both GrayWolf and IAQ sensor node that has been developed to derive the linear conversion model for CO2, VOC and CO sensors following the method that have been proposed. To propose the usefulness of the derived conversion models, the derived models have been applied to a second measurement data obtained using a sensor system in different gas concentrations to compare the result.

In (Shah et al., 2018), project has used Arduino Uno, MQ135, ESP8266, MQ6, Buzzer, Temperature and Humidity sensors. The MQ135 sensor was used to sense the NH3, NOx, alcohol, Benzene, Smoke, CO2. It will give the pollution level in PPM (parts per million). The set air quality safe level is 350 PPM and should not exceed 1000 PPM. When the value is below the 1000 PPM, the LCD will display 'Fresh Air' and 'Poor Air, Open the Windows' as the value exceed 1000 PPM. In the meantime, the buzzer will keep beeping and alert the user on the phone through GSM.

From the previous research, we have found that many research products are not equipped with anomaly notification which is crucial to ensure appropriate action can be taken as soon as possible after the detected anomaly case. To overcome the problem, a smart factory healthy workplace monitoring system system is proposed. Making a monitoring system in the factory is a good idea that will help control the air quality in the factory. This system also will help the worker to improve their health. This monitoring system will detect pollution. Then, it will analyze and monitor the air quality. The system will display the data in the LCD and the application used. This monitoring system also will trigger an alarm and send a warning message to the user to notify them. By this method, the problem will be solved.

Research Methods

This research has used Rapid Application Development (RAD) Model as a development reference. RAD has 4 phase of development, which is requirements planning, user design phase, construction phase and cut-over phase.

1. Prototype Design

   To develop the system, we need to list the hardware and software used to complete the project. The hardware and software are listed in Table 1. Figure xxx shows the project's design, which consists of an MQ 135 sensor, Wi-Fi Uno-Based ESP 8266, buzzer, LCD and Blynk application. The buzzer and the Blynk are used to notify the user if the air quality exceeds the threshold. The air quality safe level is set to 350 PPM and should not exceed 1000 PPM. Air quality level exceeding 1000 PPM causes headaches, sleepiness, and stagnant, stale, stuffy air, and if it exceeds 2000 PPM, then it can cause increased heart rate and many other diseases (Inian, 2019).

Table 1. Hardware and Software for Development

Hardware	Software
Wi-Fi Uno-Based ESP8266	Arduino IDE 1.8.5
MQ 135 Air Quality Sensor	Blynk Application
Buzzer	
LCD	

Figure 1 shows the project's design, which consists of an MQ 135 sensor, Wi-Fi Uno-Based ESP 8266, buzzer, LCD and Blynk application. The buzzer and the Blynk are used to notify the user if the air quality exceeds the threshold. They also will display the air quality value. The figure also shows the flowchart starting when the system is activated; the MQ 135 sensor will detect and monitor the air quality of the factory. Then, the data value will be displayed in the LCD and Blynk applications. When the value that has been detected exceeds the threshold, the system will alert by triggering the alarm and sending a message to notify the user.

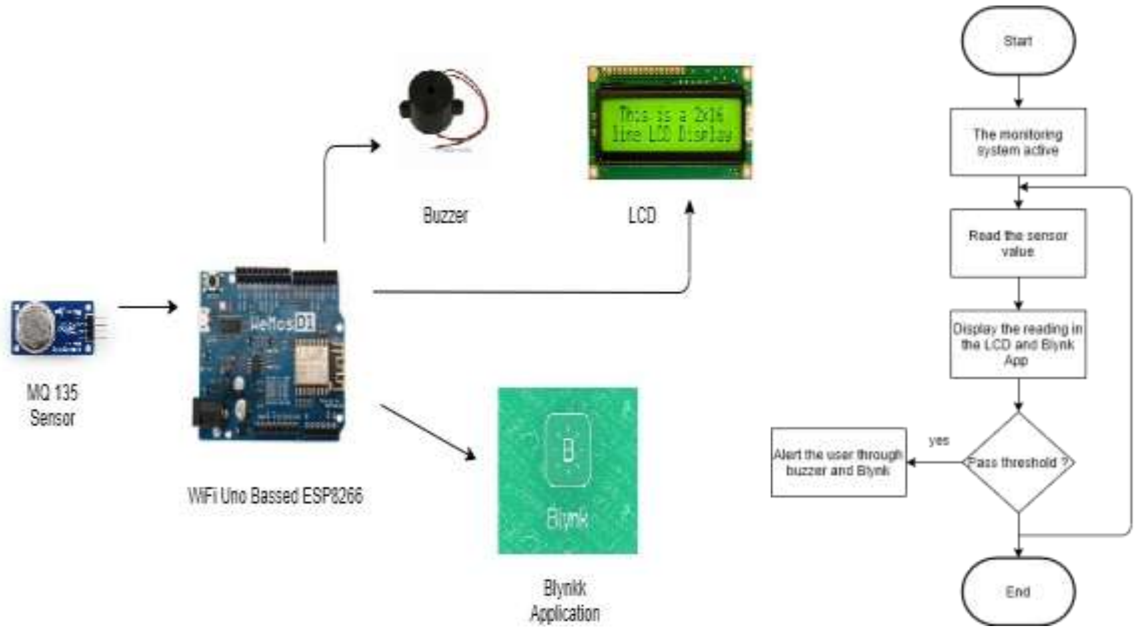

Figure 1. Design and Flowchart of The Project

2. Prototype Development

The proposed system is developed based on the IoT three-layer architecture, perception layer, network layer and application layer, described as follows:

- The perception layer is the physical layer, with sensors for sensing and gathering environmental information. In this project, MQ 135 sensor is used to collect input from the environment using microcontroller ESP8266.
- The network layer is responsible for connecting to other smart things, network devices, and servers. Its features are also used for transmitting and processing sensor data. In this project, embedded WIF in ESP8266 is used to transfer the collected data into a cloud application.
- The application layer is responsible for delivering application-specific services to the user. In this project, Blynk Application is used in the application layer to store data. The Blynk application also allows users to view and analyze the collected data to be used in the smart application. In this case, the application is also used to notify the user when an anomaly case occurs. The notification will help to monitor users to take proper action when the air condition reaches a dangerous level as set up in the system.

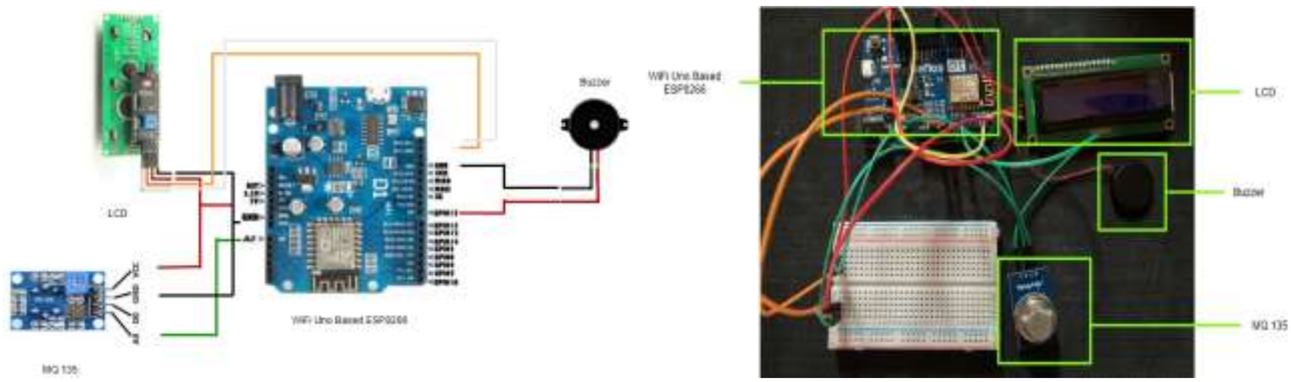

Figure 2: Design and Flowchart of The Project

Figure 2 shows the circuit design and the developed prototype. The Wi-Fi Uno-Based ESp8266 will be connected with the MQ 135 using the analogue pin. The board also will be connected to the LCD and buzzer. The buzzer is used to give an alert to the user, while the LCD will display the value of the air quality. Table 2 shows the connection between LCD, buzzer and MQ135 sensor with ESP8266.

Table 2. Pin Connection Between ESP8266 with MQ135, LCD, and Buzzer

Wi-Fi Uno-Based ESP8266	5V	GND	A0	SCL D15(GPIO5)	SDA D14 (GPIO4)	D6 (GPIO15)
MQ 135	5V	GND	A0	-	-	-
LCD	VCC	GND	-	SCL	SDA	-
Buzzer	-	Negative (-)	-	-	-	Positive (+)

Results and Discussion

In this section, testing results will be discussed. The developed prototype is tested using three objects which are lighter, perfume and aerosol. These objects are selected based on gas components inside that objects that can be detected by the MQ135 sensor. The gas components are shown in Table 3.

Table 3. Gas Composition Inside the Tested Object

Gases	Cigarette Lighter	Perfume	Aerosol
NH3			✓
NOx	✓	✓	✓
Alcohol	✓	✓	
Benzene	✓	✓	✓
Smoke	✓		✓
CO2	✓		✓

Figure 3 shows the testing results of the developed prototype, where the data is presented using the Blynk application. From the graph, it can be seen that the prototype can detect the gases inside the three objects, and a notification will be displayed when the gas value exceeds the dangerous level, which is 1000 ppm, as set up in the system during the development process.

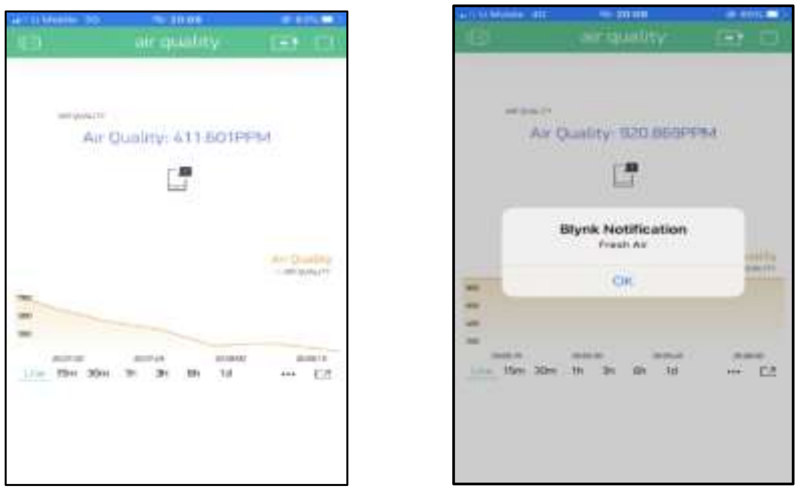

Figure 3: Blynk Dashboard and Notification for Anomaly Case

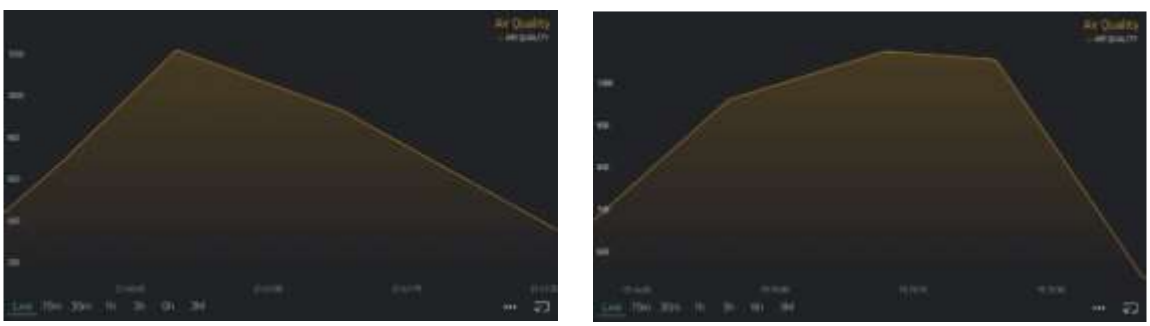

Figure 4. Detected Air Level Quality for Cigarette and Aerosol

Figure 4 shows the testing results of the developed prototype and shows the graph of when the sensor detects the gases in the aerosol. From the graph, it can be seen that the prototype is able to detect the gases inside the three objects, and a notification will be displayed when the gas value exceeds the dangerous level, which is 1000 ppm.

Conclusions

In this paper, the design and development of a healthy workplace monitoring system are discussed. The system is developed to provide a safe workplace, particularly for smart factories, to ensure worker health. The worker's health will affect the factory's productivity, leading to an increase in company profit. The developed prototype is developed using a low-cost microcontroller ESP8266 with MQ135 sensors. The collected data is transferred to the user application using a Wi-Fi connection. The developed prototype is well-functioned and meets a low-cost IoT application requirement with a three-layer architecture.

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