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# Microcontroller Based Environmental Pollution Monitoring System though IoT Implementation

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***Abstract*—The rapid increasing rate of sound and air pollution have become one of the most consequential issue nowadays in the metropolitan cities, as higher decibels of noise and toxic elements available in the air directly influences both human health and life and introduces large number of complicated diseases all over the world. Henceforth, it has undoubtedly become extremely important to monitor and control both air and sound pollution to ensure and maintain a healthier livelihood and better ecosystem. So, in this paper we proposed and implemented an automated microcontroller-based air and sound pollution monitoring and notifying system that can help to reduce the negative effect of the pollutions mentioned above and helps to take anti-pollution measures by informing the pick hours in the day-time through sufficient information via digital pathway. Our proposed system detects harmful gas elements and higher decibels of noise through the embedded sensors integrated with the microcontroller. The sensors interact with the microcontroller through the data taken by it and the microcontroller processes those data and transmits them over an online server with the help of IOT (Internet of Thing) analytic service platform. The system detects major harmful particles like NH3, CO2, SO2, CO etc. available in air and higher decibels of noise through IOT and also helps with live updates of the pollution level of a certain area. The concept of IOT helps to access data even from any remote location so that anyone can actually even avoid the possibility of physically being present in the polluted area.**

***Index Terms*—MQ-135 sensor, MQ-7 sensor, KYO37 sensor, ESP 8266 Wi-Fi module, IOT, Thing Speak**

## I. INTRODUCTION

Environmental pollution is not only a serious issue for under developed or developing countries like Bangladesh but also became a thoughtful matter for the developed countries all over the world. Environmental pollution of a particular area can be measured via different parameters like air, sound, water, soil etc. But the most affecting two parameters that is lethal for both human and wild life are sound and air pollution. In 2015, around 223 people (per 100,000 individuals) in India and 121 people (per 100,000 individuals) in China died from exposure to air pollution (indoor and ambient outdoor) [1]. Experiencing loud noise for a long time in a regular basis can cause serious health issues like stress, poor concentration in education or work, productivity losses in the workplace, difficulties while communicating with other people, fatigue from lack of sleep and sometimes more serious issues such as cardiovascular disease, cognitive impairment etc. [2]. Whereas short-term experience to air pollution can aggravate lung disease, asthma attacks and increase susceptibility to respiratory infections and can cause heart attacks and arrhythmias in people with heart disease [3]. Besides that, when pollutant gas concentration (in parts per million/ ppm) of a particular area crosses a threshold limit, people of that area may feel slight headache, fatigue, dizziness, and nausea after being exposed there for two to three hours. So, now it's high time to think more seriously about environmental pollution in order to secure a healthy life for our future generation. Our monitoring system can reduce these effects on human life by providing adequate information over IOT (Thing Speak platform) and hence can notify about the level of pollution of a certain area.

This paper is structured as follows. In Section II we discussed the earlier researches that has been done on pollution monitoring system. The flowchart of our proposed model is stated in Section III, basic idea behind the model is defined in Section IV and the software simulations related to the model development are described in Section V. Setting up the Thing Speak platform for IOT implementation is specified in Section VI. Hardware implementation described in Section VII. Result and Cost analysis of our model are presented in Section IX and X. Future ideas and conclusion are defined in Section XI and XII respectively.

## II. LITERATURE REVIEW

Environmental pollution detection and its potential effect on human health has become one of the major topics of research over the last few decades. But the involvement of modern technology in this area has moved to it's peak in the current decade. In the year of 2009, a project named Noise Tube was used to detect source of noise, personal exposure to noisy areas and henceforth to create a record of noisy areas for 241 cities around the world [4]. NoiseSpy was another invention of E. Kanjo that used the hearing aid of a mobile phone to detect the noise level of working environment [5]. In 2017, a "request & respond" and data centric protocol based internal air quality monitoring system was designed for domestic environment by Okokpujie, Orimogunje, Noma-Osaghae and Alashiri [6]. Another microcontroller-based sound and air pollution monitoring device was proposed by Chaitanya, Shruti and Raste in early 2017 [7]. But the work didn't mention the units of measurement level together with where the device was used to collect data. Another air and sound pollution monitoring system for a particular locality of Croatia named Zagreb was projected in late-2017 [8], which used both a wearable sensor for air quality measurement and a mobile crowdsensing application for sound noise level detection. But the proposed model seemed very challenging while calibrating different brand mobile phones for accurate collection of data (noise level). Another air pollution measurement system was designed in 2018 by the researchers from Covenant University, Nigeria [9]. The device collected data (environmental parameters) for pollution detection through a sensor and after processing that data it used a Wi-Fi module to transmit data in a cloud server. But they proposed module didn't mention from which area (industrial/ domestic) did they collected the data from, in what time span (early morning / mid-day/night) the data was collected and which pollutant gasses they detected mainly. Besides that, the model didn't compare the collected data with any standard level (in ppm) of pollutants that can define whether the selected area is polluted or not.

## III. Flowchart for the Proposed Model

The proposed model has two parts to monitor environmental pollution level. The first part follows the flowchart shown in Fig. 1, where a sound sensor is used to detect sound level (in db) in a particular area. If the sensor input is greater than 80 db then the display device shows a message and bar graph regarding the level of pollution. And finally sends the sensor input to a cloud environment via IOT.

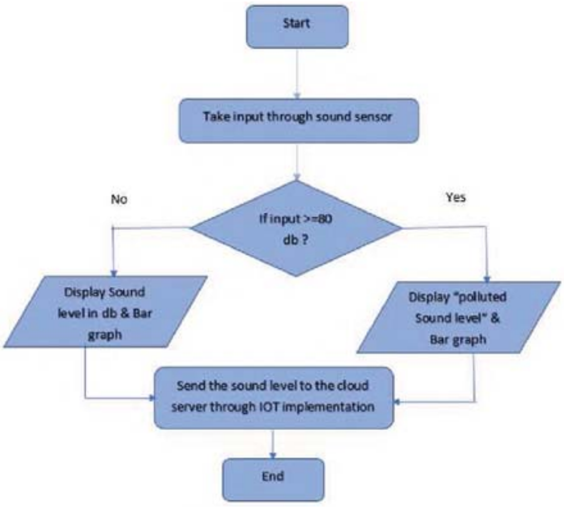



Fig. 1. Flowchart for sound pollution monitoring system.

The second part flows the flowchart shown in Fig. 2, where gas sensors are used to detect pollutant gas (in ppm) available in a particular area. If sensor input is greater than 150 ppm then the display device shows a message regarding the level of pollutants available in the area. And finally sends the sensor input to a cloud environment via IOT for further processing.

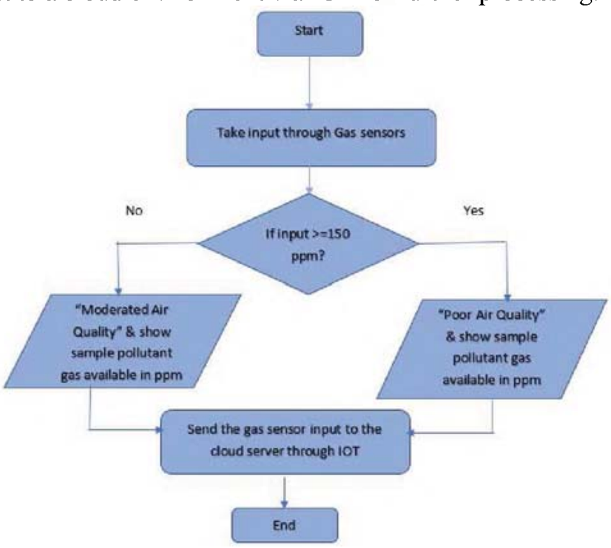



Fig. 2. Flowchart for air pollution monitoring system.

## IV. Basic Idea of the Proposed Model

It can be seen from the block diagram in Fig. 3, that in the proposed module gas sensors (MQ7 & MQ135) are used to sense the presence of harmful gases/compounds (Carbon Monoxide, CO2, Ammonia etc.) in the air and KY037 sound sensor is used to measures the sound level constantly. The sensor inputs are then processed and presented to the user through a SPI OLED Display and transferred to a cloud storage via a ESP8266 WiFi module. The whole process is centrally controlled through an Arduino Uno. And Fig. 4 depicts all the steps followed to design the proposed model.

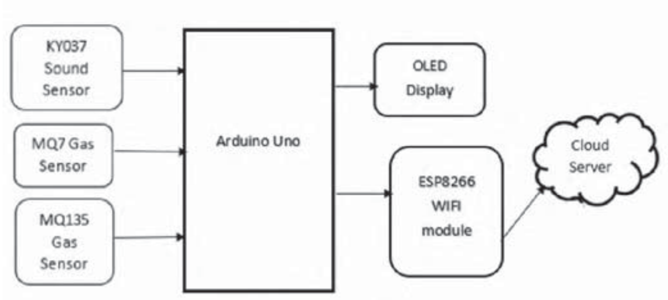



Fig. 3. Block diagram for air & sound pollution monitoring system

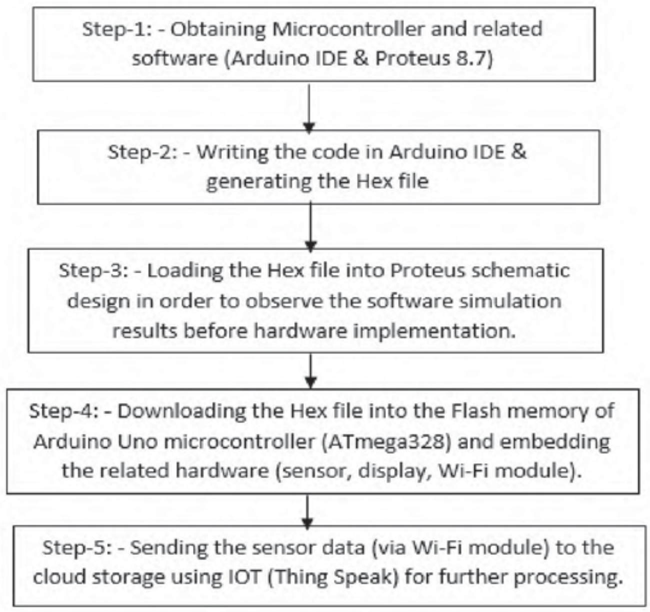



Fig. 4. Steps to design the Proposed model.

## V. Software Simulation for the Proposed Model

The circuit diagram of Arduino based sound pollution monitoring system using KY037 Sound sensor is shown in Fig. 5. In the simulation, a normal sound sensor is used with a logic toggle switch to simulate the high sound. Here the switch connected to the sensor's analog pin worked as a high input to the sensor. It can be seen from Fig. 5 that when sound sensor senses a high logic via the logic toggler then the display shows a message "Loud sound is detected". But when the sound sensor senses a low logic, the display shows "Loud sound is not detected".

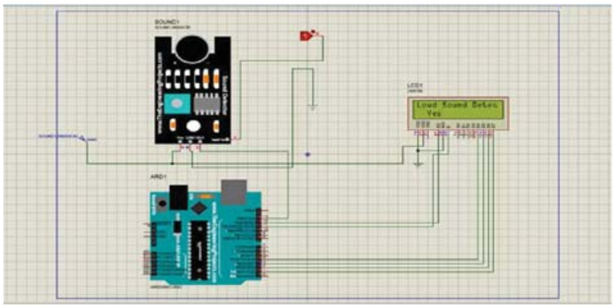


Fig. 5. Simulation result of KYO37 sound sensor in Proteus platform.

The circuit diagram of Arduino based air pollution monitoring system using gas sensor is shown in Fig. 6. In the simulation process, gas sensor is used with a logic toggler switch to detect the polluted gas. The switch connected to the sensor's analog pin worked as a high input to the sensor. Here Fig. 6 shows, when gas sensor senses a low logic then via the Uno the system shows that polluted gas is not detected. But when the gas sensor senses a high logic, the display shows that polluted gas is detected.

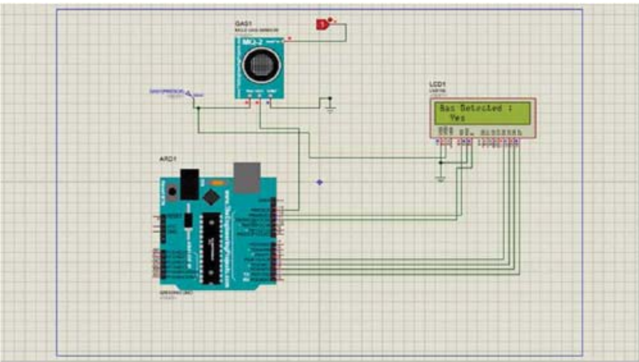


Fig. 6. Simulation result of gas sensor in Proteus platform.

## VI. SETTING UP THING SPEAK FOR IOT IMPLEMENTATION

At first an account was created at Thing Speak (https://thingspeak.com/) platform. After creating the account. It was verified through the email to fully utilize the available options on the website. Then a new channel was created with the following:

1. MQ135 Name: Home air reading.
2. Field 1: Analog Reading. (Tick mark in the box).

Then Save Chanel option was clicked in order to finish the channel creation.


Fig. 7. Creating New Channel

After creating the channel, the API key was noted down from the "API Keys" option located in the channel menu. This API key was later used in the proposed model in order to upload the data recorded by the Gas/Sound sensor to the Thing Speak channel.

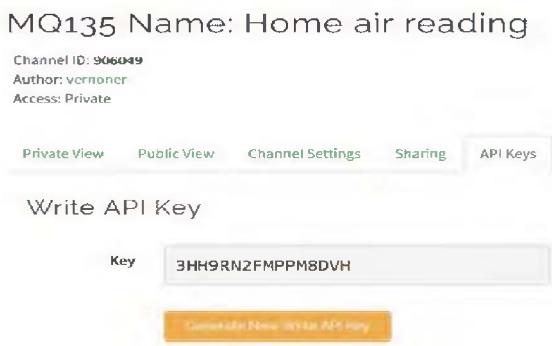


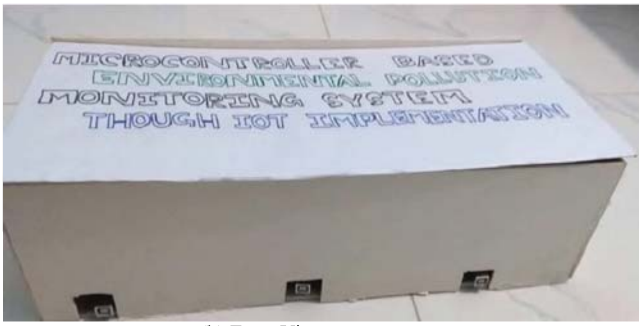

Fig. 8. Creating API Key.

## VII. HARDWARE IMPLEMENTATION OF THE PROPOSED MODEL

The hardware prototype of the portable Arduino based environmental pollution monitoring system with embedded sensors are shown in Fig. 9. The sound sensor's Analog pin is connected to A0 pin of the Arduino Uno board. To display the sound readings in dB (decibels), a 0.96-inch white SPI OLED display is connected to the Arduino Uno. The 5 different data pins of the dispaly module (MOSI, CLK, DC, CS and RESET) are connected to pin 3,4,5,6, and 7 of the Arduino Uno respectively. The analog pins of Uno board are used as input pins and the digital pins are used as output pins.

Here pin A0 of the Uno board is set as input. When a sound is sensed by the sensor, it produces an analog voltage which is sent to the Arduino Uno's analog pin A0. Then after processing the data sensed by the sensor through Arduino Uno, the OLED display shows the sound level (high/medium/low) present in the area through a bar graph alongside the level of pollution unit measured in db.

(a) Top View




(b) Front View

Fig. 9. Hardware prototype of the environmental pollution monitoring system.

The working principle of both the sensors (MQ-7 & MQ-135) are same, except MQ-135 measures the level of carbon dioxide present in the environment whereas carbon monoxide present in the environment is measured by MQ-7 sensor. The gas sensor's analog pin is connected to A0 pin of the Arduino Uno. Here pin A0 is established as input. So, when gas is detected by the sensor, it produces an analog voltage which is sent to the Arduino Uno's analog pin A0. Then the achieved analog voltage is processed by Arduino Uno, and converted into ppm (parts per million) unit. The ESP8266 Wi-Fi module is connected to the Arduino Uno's pin 10 and 11 through Rx and Tx respectively. The Wi-Fi module is used to receive the data from the microcontroller and send it to the Thing Speak cloud server where the data can be seen live.

## VIII. WORKING PRINCIPLE OF THE PROPOSED MODEL

It can be seen from Fig. 10 and Fig. 11 that the pollution monitoring system is divided into two modules (one for sound level detection and another for pollutant gas detection). The portable KY037 sensor-based module senses sound from the surrounding, converts it into db (decibel) unit. And finally, transmits the sensed data to the server database through IOT cloud platform and also shows it on the OLED display to create awareness among the users. Most of the pollutants or polluted gas formed in the air of industrial area are Carbon Dioxide and Carbon Monoxide. During the pick hours of the day while their production level hits the maximum range, the availability of these gases also reaches to its pick level. These pollutants are extremely harmful for those who are inhaling them through breathing while their present in the production area. Thus, in the proposed model a MQ7 and a MQ135 sensor is used as a pollutant analyzer because MQ135 and MQ7 are highly sensible to gases like CO2, Bengine Athenomox, Ammonia and Carbon Monoxide. At first the device is kept in a place near the production area of the selected industry for data collection through the sensors. Then the data (ppm level of the pollutant gases) collected by the Arduino Uno via the sensors are transmitted to the server database with the help of IOT cloud platform (Thing Speak). The IOT cloud platform is used to receive and store the sensor transferred data to the server database with help of a Wi-Fi module (ESP8266 ESP-01). And by processing and analyzing all the data from the server database the proposed model can finally come up with the conclusion that which time of the day the pollutant level (in ppm) in the air is high, so that the respective authorities of the industry can take effective measures to keep the pollution level low.

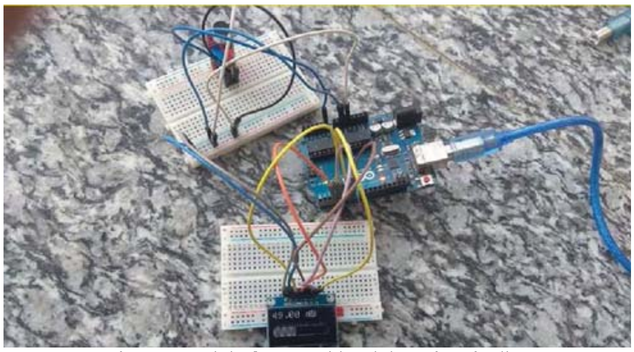


Fig. 10. Module for Sound level detection (in db).

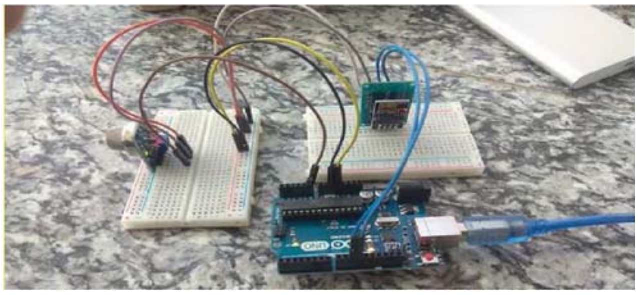


Fig. 11. Module for Pollutant gas detection (in ppm/parts per million).

## IX. RESULT ANALYSIS

The proposed model is used for measuring the sound pollution/intensity level near educational institutions, hospitals and corporate offices. Before taking final data, the sensor was calibrated at the beginning. For measuring the pollution level, we chose schools, colleges, corporate offices and hospitals where traffic is busy all the time. To demonstrate the effect of sound pollution on these places, we took two set of measurements with the proposed model, one set in the early morning and another set in the busy hours.

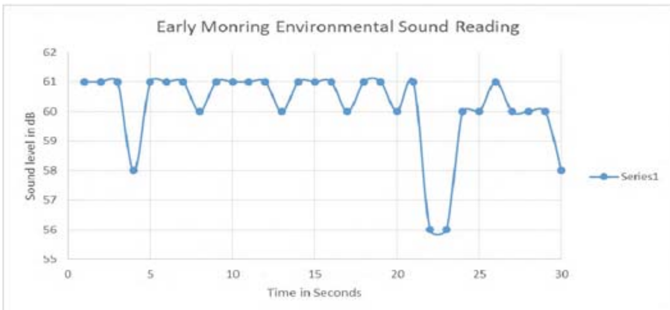



Fig. 12. Early morning reading via sound sensor in Thing Speak Platform.

It can be seen from Fig. 12 that in the early morning (between 7:00 am to 8:00 am), a time frame of 30 seconds was taken from 1 hour and the sound pollution is not severe at that time slot. The sound level was around 60.1 db at that slot as there were minimal traffic on the road and presence of people were negligible at that time.

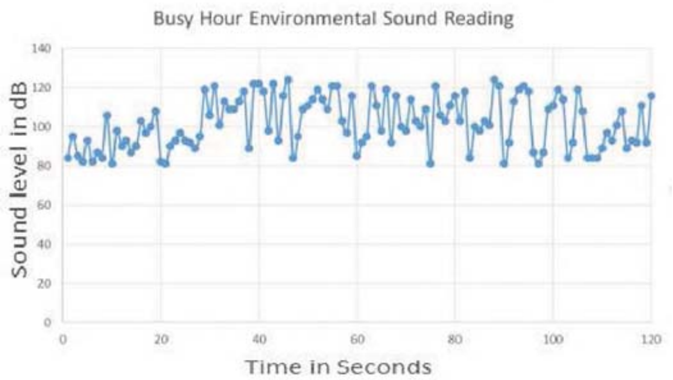



Fig. 13. Busy hour reading via sound sensor in Thing Speak Platform.

During the busy hours (between 9:00 am to 11:00 am) of the day, when we took the second set of data the traffic became busy and the presence of people around those area increased. And it can be seen from Fig. 13 at that time frame, the average reading was 101.7 db, a lot higher than the reading taken at early morning. According to National Centre for Environmental Health, noise from any source above 70 dB over a prolonged period of time may start to damage our level of hearing and loud noise above 120 db can cause immediate harm to our ears [10]. Thus, it can be said that the readings taken by the proposed model is almost accurate as in the early morning the noise level was around 60.1 db (equivalent to normal conversation) and during busy hour the noise level was above 120 db. And using this device the user can take decision about avoiding places with high level of pollution.

Another parameter that we used to detect the level of environmental pollution was pollutant gas (CO, $CO_2$, $NH_3$) present in the air (in ppm unit). For this purpose, we picked a garment factory and a brick kiln as locations for air quality testing through the proposed model. To demonstrate the effect of air pollution on the mentioned places, we took two set of readings with the proposed model, one set in the early morning and another set in the busy hours (during full production time).

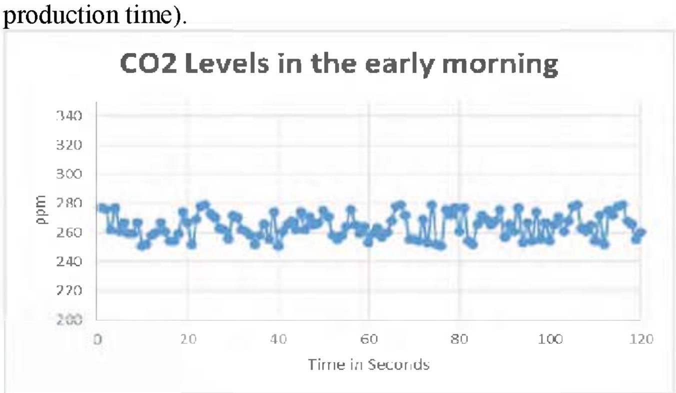



Fig. 14. CO2 level measurements in Thing Speak platform at early morning

After the calibration phase, we started to take our first set of readings through the MQ135 sensor to measure the average level CO2 available in the garment factory. It can be seen from the live data (available at Thing Speak platform) in Fig. 14 and Fig. 15 that the average CO2 level was mostly around 264 ppm (at early morning) and around 464 ppm (during full production time). According to Wisconsin Department of Health Services, the concentration level of CO2 ranges within 400-1000 ppm in an occupied space where good air exchange facility is available [11]. And the garment factory we visited for testing our proposed model had very good ventilation facilities. So, it can be said that the CO2 reading taken by our proposed model (through MQ135 sensor) is almost accurate. And using this device big industries can improve their ventilation facility to reduce air pollution.

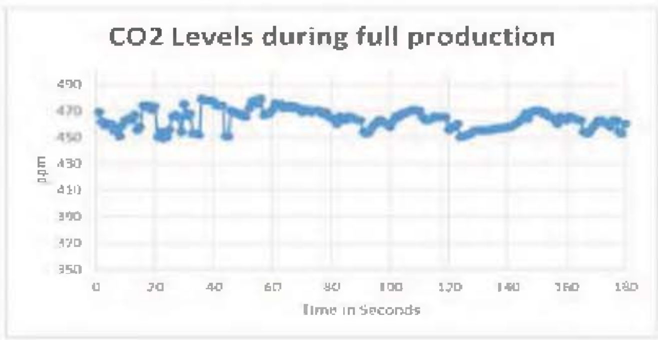



Fig. 15. CO2 level measurements in Thing Speak platform during full production time.

We used a MQ7 Sensor at the brick kiln to measure the level of Carbon Monoxide available in the atmosphere. For this, we took two readings in different times with our instrument, one while there was no production taking place at the kiln and the other one when the full production took place at the kiln.

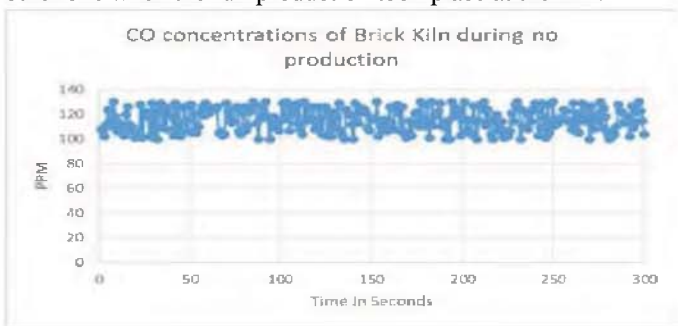



Fig. 16. CO level measurements in Thing Speak platform at early morning.

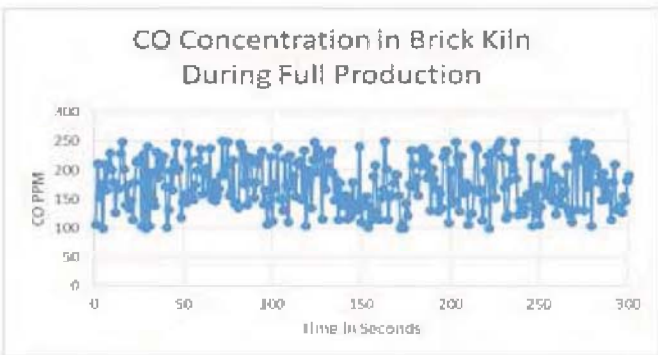



Fig. 17. CO level measurements in Thing Speak platform during full production time.

It can seen from Fig. 16 that during no production time, the average CO concentration was 115.75 ppm, which is quite safe for any adult over an eight-hour exposure period [12]. Even when there was no production, raw bricks were still being made from soil and they were prepared in large numbers before the production started. The raw brick making procedure includes steps which also causes minor air pollution and that's why the nominal reading can be achieved during no production period. However, when full production started, a large area was dedicated to burning the raw brick near the kiln and the area was highly polluted for the workers. It can be noticed from Fig. 17 that during full production time, the achieved reading was mostly above 200 ppm.

When the concentration of CO in the air crosses 200 ppm threshold level, people may feel Slight headache, fatigue, dizziness, and nausea after being exposed there for two to three hours [12]. Thus, it can also be concluded that the reading taken by the proposed model is quite accurate, as in the brick klin the CO level was mostly above 200ppm during full production time. Which is why it can be advised to the brick klin authorities to have a huge number of manpower invested in the job so that they can work in shifts to avoid sickness due to pollution**.**

## X. COST ANALYSIS

TABLE I
COST ANALYSIS

| Component List | Quantity | Cost (in BDT) |
|---|---|---|
| Arduino UNO R3 | 03 | 1200 |
| Bread Board | 03 | 225 |
| Jumper Wires | as per requirement | 70 |
| MQ-7 Sensor | 1 | 250 |
| MQ-135 Sensor | 1 | 200 |
| KYO37-Sound Sensor | 1 | 170 |
| OLED Display | 1 | 600 |
| ESP 8266 Wi-Fi Module | 1 | 200 |
| ESP 8266 Wi-Fi Module Adapter | 1 | 200 |
| Total= | | 3115 BDT<br>37.10 USD |

The overall cost analysis of our proposed model is depicted in Table I. And our proposed model costs around 3115 Taka or 37.10 USD, which is quite cheap as compared to other traditional pollution monitoring system available in the market.

## XI. FUTURE WORK

In our paper, we proposed a microcontroller-based environmental pollution monitoring system through IOT (data stored in cloud storage) implementation. As the system is equipped with multiple sensors, so in order to provide real time data for a long time the sensors might get overheated. Thus, to avoid this hassle, as a future modification a cooling device can be added with existing system. The sensors used in the proposed model has a very short range of coverage, so replacing them with expensive sensors will cover more wider range of detection area in future. Besides that, use of Nano sensors and PCB layout design can also be implemented in future to make the device more compact.

## XII. CONCLUSION

Previously many organizations, scientists and research groups have put unending collaborative effort to propose and construct microcontroller-based pollution monitoring system which resulted in more expensive integration of the system. But our proposed model is very cost effective, handy and embedded with components that consumes reasonable amount of power. The consequence of our design is a fast, easy to operate module. Moreover, our proposed model is designed concerning the socio-economic condition of developing countries and will be very convenient for the inhabitants of areas where pollution is a of far more concern. Besides the device will be causing nearly zero maintenance cost once implemented and embedded. Another fascinating feature of our proposed model is to report the user with live data through IOT (cloud storage) implementation, which helps the user to avoid the polluted area as soon as it gets polluted.

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