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ARTICLE

Air Pollution Monitoring System Using Micro Controller Atmega 32A and MQ135 Gas Sensor at Chandragiri Municipality of Kathmandu City

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ABSTRACT

Air is one of the essential elements of human's surroundings. The earth's atmosphere is full of air which contains gases such as Nitrogen, Oxygen, Carbon Monoxide and traces of some rare elements. But quality of the air has been degrading for some decades due to various activities conducted by the human beings that directly or indirectly affect the atmosphere leading to the air pollution. There are different techniques to measure air quality. However, with the evolution of time the expensive and less efficient analog devices have been replaced by more efficient and less expensive electronics device. In this research, MQ135 sensor is used to measure air quality of a particular location. I2C display is used to monitor the data. Indeed, with the increasing in number of vehicles, unplanned urbanization and rapid population growth, air pollution has considerably increased in the last decades in various areas of Kathmandu. Thus, this project 'Air Pollution Monitoring System' was focused on collection of the data specific location of Chandragiri municipality of Kathmandu city. In conclusion, analysis of the data is done with the help of origin software which shows that the Arduino device in this device works perfectly for measuring the air pollution. Air quality of the selected area is found to be less than 500 PPM which concludes that the air quality of this area is normal.

1. Introduction

Air is one of the essential elements of human's surroundings. The earth's atmosphere is full of air which contains gases such as Nitrogen, Oxygen, Carbon Monoxide and traces of some rare elements. Humans, animals as well as plants need an atmosphere of air that is free from contaminants which is very crucial for human life and health. But quality of the air has been degrading for some decades due to various activities conducted by the human beings that directly or indirectly affect the atmosphere leading to the air pollution. Air pollution is the biggest problem of every nation, whether it is developed or developing. IoT based air pollution monitoring system was developed and used to monitor and collect the data related to air pollution. Wi-Fi module ESP8266 was used to con-

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nect the system with the internet. It showed the air quality in PPM on the LCD. It can be used easily to check the air quality of the specific areas in real time [1].

According to World Health Organization (WHO), air pollution is defined as contamination of the indoor or outdoor environment by any chemical, physical, or biological agent that modifies the natural characteristics of the atmosphere. Common sources of air pollution are household combustion devices, motor vehicles, industrial facilities, unplanned urbanization, rapid population growth and forest fires [2]. Air pollution is the presence of extra unwanted biological molecules, particulates or other harmful things into the earth atmosphere. It is a major cause of infections, allergies, and eventually reasons of death to some peoples. A variety of respiratory and other diseases, which can also be fatal, are caused by outdoor and indoor air pollution. The world health organization (WHO) in 2014 approximated those 7 million people deaths worldwide because of air pollution [3].

Air pollution is a complex mixture of thousands of components, majority of which include airborne Particulate Matter (PM) and gaseous pollutants like ozone (O_3), nitrogen dioxide (NO_2), volatile organic compounds (like benzene), carbon monoxide (CO), sulfur dioxide (SO_2), etc. [4].

Day by day the air is degrading in a dangerous manner. Same rate of degradation may lead to not only environment degradation but also affect the health of the human beings and other living organisms. So, minimization and control of air pollution and alerting people about the growing air pollution is of significant importance to alleviate particular actions to limit it [5].

Sensors have become less expensive, smaller, and more energy efficient as sensing, processing, and transmission technologies have advanced. However, WSN system performance is still influenced by unit computation speed, memory capacity, and connection stability, among other factors. Many difficulties in WSN software, such as routing protocols, media access control, coverage, and power management, have been discussed in conjunction with hardware restrictions [6]. A sensor node is made up of several parts, such as a transmitter, data processing components, receivers, and an energy supply. Sensor nodes are in charge of sending information discovered through their sensing abilities to following sensor nodes or sink nodes. The sensor component of the system measures a variety of environmental characteristics such as gases, smoke concentrations, and dust particles, among others [7].

2. Literature Review

Innumerable works had been carried out till today throughout the world regarding air pollution monitoring system. Air pollution and air quality in real time has been monitored with different process and methodology be using different devices and software [8]. To measure the air quality, similar work has been done with IoT based system by using data processing node (Raspberry's Pi). MQ135 sensor has been used to measure air quality. The data are stored in Raspberry's Pi and displayed on-screen and on other devices. The python code has been used to operate with Raspberry Pi. However, Raspberry pi is very expensive as compared to the Arduino board. Arduino is cheap and easy to use for students or researchers [9].

Similarly, air pollution monitoring system based on IoT and artificial intelligence has been developed which gather the data and alert the personnel immediately while the threshold level of pollution exceeds. This system fulfilled the humanitarian need by tracking the quality of air that people breadth in high traffic areas and possessed a health risk by alerting people to unhealthy level of these sensed pollutants. It is a low-cost and high-fidelity air quality monitoring system that can be used in school areas, in factories as well as in hospital areas [10].

Likewise, another device Arduino-based real time air quality and pollution detector has been developed. It has used MQ135 as a gas sensor which is linked with Arduino Uno board. This system has checked the air quality of cigarette smoke, coil burning smoke, vehicle smoke from street etc. with respect to time and the distance. This system can be developed and used even by students since it is reliable as well as low costing for collecting and analyzing the data related to air pollution [11].

Further, IoT based air pollution monitoring system had been developed. This system used on Arduino Uno R13 microcontroller as air pollution monitoring equipment. Arduino Uno device is connected with ESP8266 module which is an extremely cost-effective board. This IoT based project allows us to monitor the pollution level of anywhere by using computer or mobile phone [12].

Another research '*Smart Environment Monitoring System by employing Wireless Sensor Networks on Vehicles for Pollution Free Smart Cities*' has been carried out. This research introduced the concept with inclusion of the Internet of Things and LTE-M modules that are low cost and more efficient system. It is more effective but expensive comparing to air monitoring device based on Arduino Uno [13].

In similar way, low power wide area (LPWA) technology, an emerging Machine-to-Machine (M2M) commu-

nications technique was used to develop the air pollution monitoring system. With the aid of the LPWA network, the air sensing data over a large coverage area is collected and transmitted to the IoT cloud in time [14].

3. Materials and Methods

3.1 Working Method of Air Pollution Monitoring System

In this system, MQ135 sensor is used to sense the air quality. The data collected by the sensor are received by Arduino Uno. Then the data so collected are displayed on I2C LCD display. Similarly, EPS8266 module connects Arduino to internet so that the data are regularly updated on the internet as well. LED lights also used to notify the level of air quality based on PPM of air pollution.

Figure 1 given below shows the block diagram of Air Pollution Monitoring System. It shows how the device works using Arduino Uno with air sensor MQ135.

Figure 1. Block Diagram of Air Pollution Monitoring System

3.2 Circuit Diagram and Working Explanation

The circuit diagram of Air Pollution Monitoring System using Arduino Uno is as shown in the figure. MQ135 sensor is connected to Arduino to measure the value of air quality of the surrounding. In this circuit, SCL and SDA are connected to analog input A4 and A5 port of Arduino respectively. Negative terminal of MQ 135 sensor is grounded and positive terminal is connected to A3 port of Arduino. The orange wire of the sensor is connected to the VCC of I2C and gray wire of I2C is grounded. Positive terminal of red, green and yellow LEDs are connected to 3, 4 and 5 port of digital (pwm) and negative terminal of terminal of red, green and yellow LED are grounded in Bread GND pin. Breadboard is powered from Arduino power pin.7 – 12 v DC power is supplied to Arduino with the help of power bank. The data collected by the sensors are directed toward I2C through Arduino and displayed in the I2C.

Given Figure 2 represents the circuit diagram of air pollution monitoring system, the figure is designed using fritzing software. It shows the connection of Arduino Uno corresponding to I2C display, LED lights and MQ135 sensors.

3.3 Field Observation and Data Collection

After constructing the device, field observation was done to test the device. Related data were collected form Chandragiri-10, Boshigaun which lies on the southern part of the Kathmandu city. Data of three different loca-

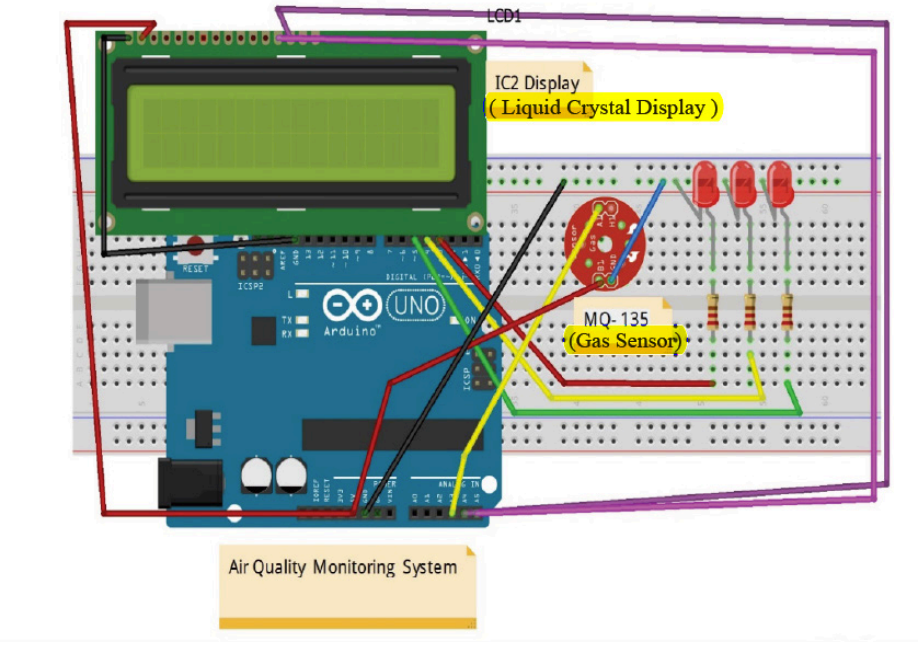

Figure 2. Circuit Diagram of Air Pollution Monitoring System

tions, Basic Learning English Secondary School, Buddha Chowk periphery and Khushi Khushi chowk within Chandragiri-10, Boshigaun were collected to observe the air quality of Chandragiri-10, Boshigaun. Data were collected for 30 minutes for three different time in morning, day and evening. Data during morning, day and evening were collected at exactly same time in three different locations.

On 2022/03/25, data were collected for 30 minutes during morning, day and evening time at 7:00 AM – 7:30 AM, 1:00 PM – 1:30 PM and 6:00 PM – 6:30 PM form Basic Learning English Secondary School.

Data collected at Basic Learning English Secondary School are shown in Table 1 below:

Table 1. Data collected at Basic Learning English Secondary School using Air Pollution Monitoring System

Morning		Day		Evening	
Time	PPM	Time	PPM	Time	PPM
7:00 AM	395	1:00 PM	342	6:00 PM	225
7:01 AM	381	1:01 PM	335	6:01 PM	230
7:02 AM	375	1:02 PM	331	6:02 PM	221
7:03 AM	363	1:03 PM	335	6:03 PM	223
7:05 AM	355	1:05 PM	312	6:05 PM	219
7:06 AM	353	1:06 PM	309	6:06 PM	217
7:07 AM	333	1:07 PM	304	6:07 PM	213
7:09 AM	315	1:09 PM	299	6:09 PM	218
7:10 AM	309	1:10 PM	295	6:10 PM	210
7:11 AM	305	1:11 PM	290	6:11 PM	209
7:12 AM	304	1:12 PM	291	6:12 PM	211
7:14 AM	302	1:14 PM	292	6:14 PM	216
7:15 AM	303	1:15 PM	294	6:15 PM	218
7:16 AM	307	1:16 PM	265	6:16 PM	219
7:18 AM	314	1:18 PM	301	6:18 PM	209
7:19 AM	323	1:19 PM	299	6:19 PM	206
7:20 AM	327	1:20 PM	300	6:20 PM	203
7:21 AM	328	1:21 PM	296	6:21 PM	205
7:23 AM	325	1:23 PM	288	6:23 PM	199
7:24 AM	330	1:24 PM	290	6:24 PM	206
7:25 AM	341	1:25 PM	292	6:25 PM	203
7:26 AM	343	1:26 PM	293	6:26 PM	199
7:28 AM	320	1:28 PM	299	6:28 PM	200
7:29 AM	315	1:29 PM	302	6:29 PM	197

Data collected at Buddha Chowk periphery are shown in below Table 2:

Table 2. Data collected at Buddha chowk Periphery using Air Pollution Monitoring System

Morning		Day		Evening	
Time	PPM	Time	PPM	Time	PPM
7:00 AM	507	1:00 PM	408	6:00 PM	238
7:01 AM	497	1:01 PM	387	6:01 PM	231
7:02 AM	492	1:02 PM	366	6:02 PM	229
7:03 AM	445	1:03 PM	347	6:03 PM	225
7:05 AM	400	1:05 PM	320	6:05 PM	217
7:06 AM	387	1:06 PM	311	6:06 PM	209
7:07 AM	394	1:07 PM	293	6:07 PM	211
7:09 AM	343	1:09 PM	277	6:09 PM	208
7:10 AM	330	1:10 PM	293	6:10 PM	205
7:11 AM	312	1:11 PM	293	6:11 PM	204
7:12 AM	300	1:12 PM	285	6:12 PM	202
7:14 AM	296	1:14 PM	284	6:14 PM	201
7:15 AM	281	1:15 PM	289	6:15 PM	198
7:16 AM	275	1:16 PM	293	6:16 PM	198
7:17 AM	276	1:17 PM	281	6:17 PM	200
7:19 AM	258	1:19 PM	283	6:19 PM	200
7:20 AM	249	1:20 PM	279	6:20 PM	199
7:21 AM	255	1:21 PM	277	6:21 PM	201
7:22 AM	251	1:22 PM	274	6:22 PM	203
7:24 AM	250	1:24 PM	263	6:24 PM	200
7:25 AM	244	1:25 PM	260	6:25 PM	199
7:26 AM	239	1:26 PM	257	6:26 PM	198
7:28 AM	232	1:28 PM	254	6:28 PM	201
7:29 AM	227	1:29 PM	252	6:29 PM	200

Data collected at Khushi Khushi chowk are shown in Table 3 below:

Table 3. Data collected at Khushi Khushi Chowk using Air Pollution Monitoring System

Morning		Day		Evening	
Time	PPM	Time	PPM	Time	PPM
7:00 AM	520	1:00 PM	443	6:00 PM	251
7:01 AM	509	1:01 PM	420	6:01 PM	289
7:02 AM	499	1:02 PM	415	6:02 PM	287
7:03 AM	498	1:03 PM	425	6:03 PM	288
7:05 AM	488	1:05 PM	397	6:05 PM	274
7:06 AM	481	1:06 PM	405	6:06 PM	270
7:07 AM	475	1:07 PM	406	6:07 PM	268

Table 3 continued

Morning		Day		Evening	
Time	PPM	Time	PPM	Time	PPM
7:09 AM	476	1:09 PM	380	6:09 PM	267
7:10 AM	468	1:10 PM	379	6:10 PM	265
7:11 AM	459	1:11 PM	381	6:11 PM	258
7:13 AM	448	1:13 PM	371	6:13 PM	254
7:14 AM	440	1:14 PM	368	6:14 PM	253
7:15 AM	438	1:15 PM	345	6:15 PM	252
7:16 AM	431	1:16 PM	349	6:16 PM	253
7:17 AM	425	1:17 PM	339	6:17 PM	251
7:19 AM	412	1:19 PM	305	6:19 PM	249
7:20 AM	408	1:20 PM	295	6:20 PM	248
7:21 AM	399	1:21 PM	285	6:21 PM	246
7:23 AM	376	1:23 PM	275	6:23 PM	246
7:24 AM	379	1:24 PM	289	6:24 PM	248
7:25 AM	370	1:25 PM	290	6:25 PM	249
7:26 AM	375	1:26 PM	281	6:26 PM	247
7:27 AM	366	1:27 PM	279	6:27 PM	246
7:28 AM	358	1:28 PM	275	6:28 PM	245
7:29 AM	350	1:29 PM	282	6:29 PM	244

4. Result and Discussion

This Air Pollution Monitoring System has been constructed by connecting sensor and other different components to Arduino Uno in a breadboard with the help of jumper wires.

Figure 3 shows the construction of the air pollution monitoring device. It also shows the connection of the Arduino Uno with I2C display.

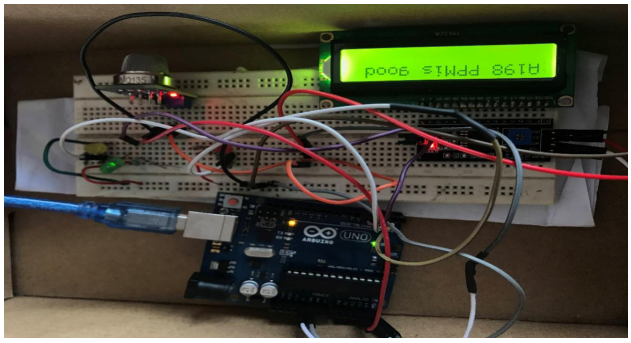

Figure 3. Arduino Uno connected with I2C display

Following variation of air quality in PPM were obtained with respect to time.

4.1 Result Obtained from Basic Learning English Secondary School Periphery Using Arduino Based Device

Figure 4 below represents the variation of PPM with respect to particular time of the data collected from the Basic Learning English Secondary School. This figure shows that the air quality of this location is better as PPM is below 500.

4.2 Result Obtained from Buddha Chowk Periphery Using Arduino Based Device

Figure 5 represents the variation of air quality obtained during those phases of time with the help of data collected from Buddha Chowk periphery. This figure shows that the maximum PPM of this location during a day is 500. In this location data were recorded on 2022/04/03 during morning, day and evening time within 7 AM to 6:30 PM.

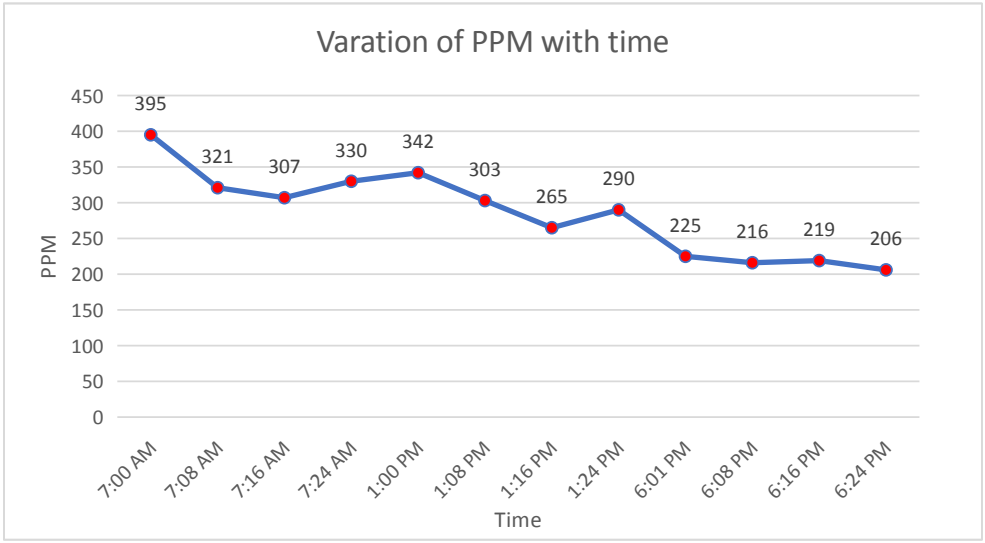

Figure 4. Variation of PPM with respect to time obtained from data recorded at Basic Learning Secondary School

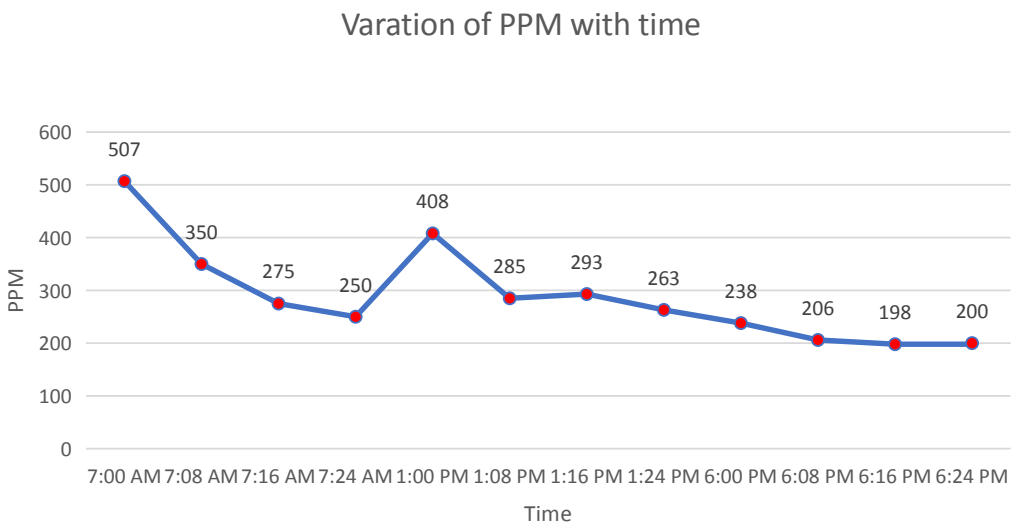

Figure 5. Variation of PPM with respect to time obtained from data recorded at Buddha Chowk Periphery

4.3 Result Obtained from Khushi Khushi Chowk Using Arduino Based Device

Figure 6 shows the variation of PPM with respect to time of Khushi Khushi Chowk. In this location data were recorded on 2022/04/03 during morning, day and evening time.

4.4 Comparison of PPM Obtained from Three Different Locations of Boshigaun

After collection of data from three different locations at exactly same time, obtained data were compared and shown in below graph.

Figure 7 represent the graph which shows the comparison of the PPM of three different location from where the data are collected. It shows that the PPM is high during morning time and gradually decreases till the evening of all three locations.

4.5 Analysis of Data

The data obtained using Arduino have been analyzed and calculation of error has been done with the help of origin software.

The analysis of the data recorded at school periphery using origin software is shown in the graph below:

Figure 8 represents the graph of linear fitting and polynomial fitting fitted between air quality (PPM) and time of Basic Learning English Secondary School.

Table 4 shows the standard error of linear fitting of the data obtained from school.

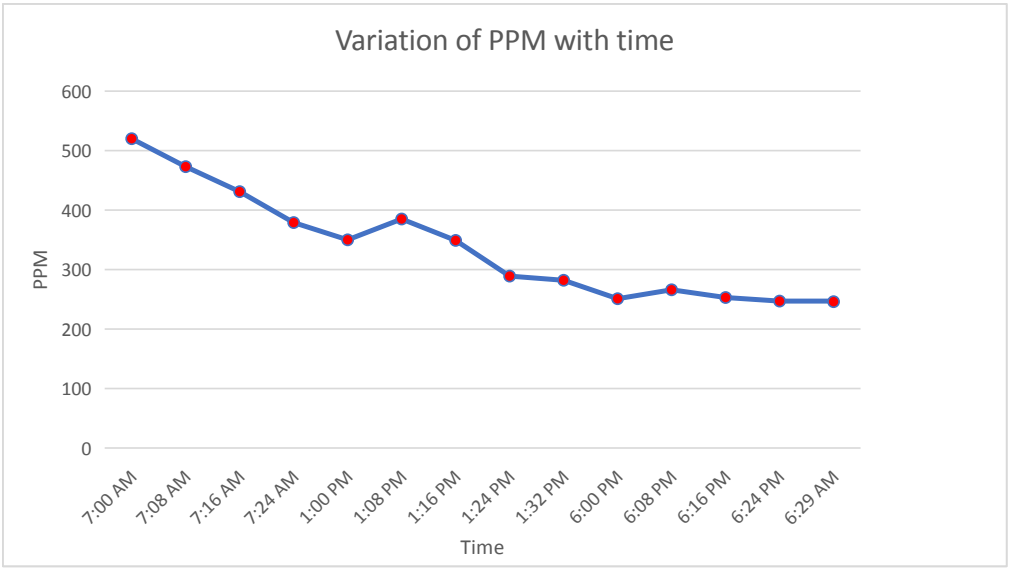

Figure 6. Variation of air quality with respect to time.

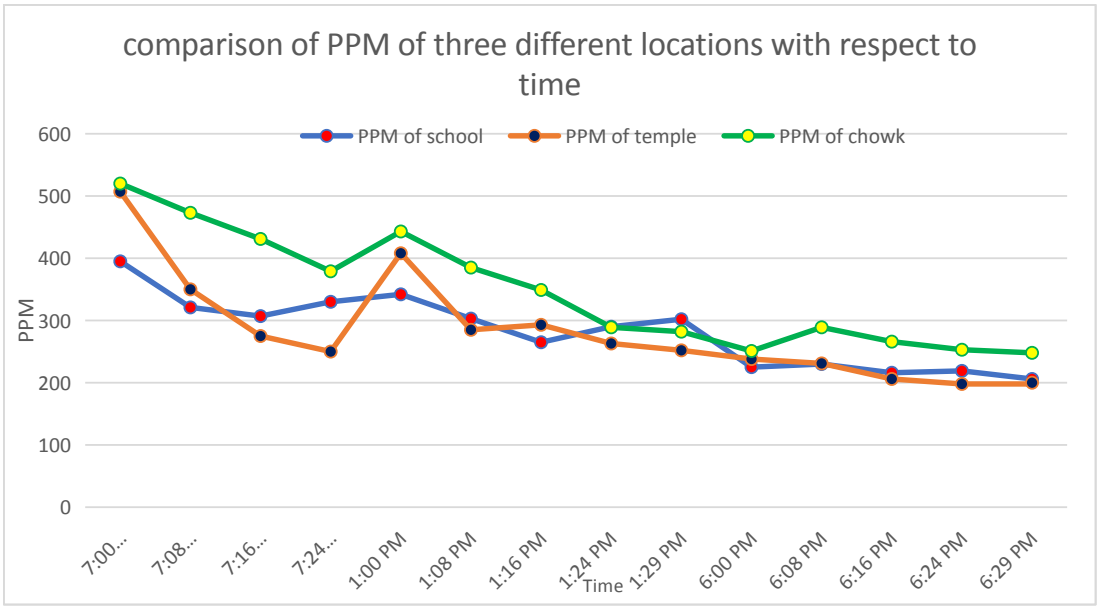

Figure 7. Comparison of PPM of three different locations with respect to time

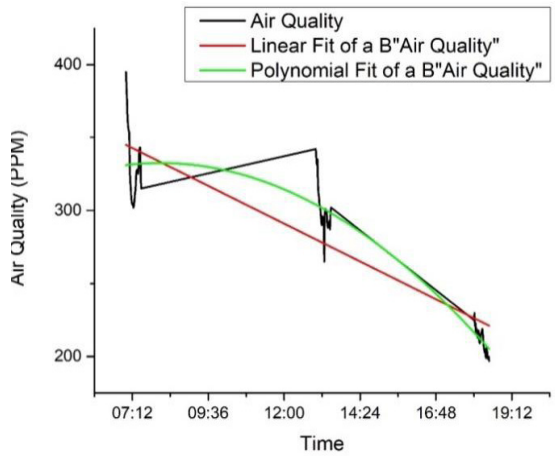

Figure 8. Graph showing the variation of PPM with time at school

Table 4. linear fitting of data obtained at school

Equation	y = a + b*x		
Residual Sum of Squares	51128.31124		
Pearson's r	–0.89729		
Adj. R-Square	0.80292		
		Value	Standard Error
Air Quality	Intercept	420.23025	7.71966
	Slope	–258.43197	13.55319

Table 5 represents the standard error of polynomial fitting of the data obtained at school.

Similarly, the analysis of data recorded from Buddha chowk is shown in the graph below:

Figure 9 shows the graph of linear fitting and polynomial fitting fitted between air quality (PPM) and time of Buddha Chowk. It analysed the data recorded at Buddha Chowk.

Table 5. Polynomial fitting of data obtained at school

Equation	y = Intercept + B1*x^1 + B2*x^2		
Residual Sum of Squares	26049.172		
Adj. R-Square	0.89844	Value	
		Value	Standard Error
Air Quality	Intercept	255.49572	18.8335
	B1	456.796	78.7527
	B2	–677.9677	74.07813

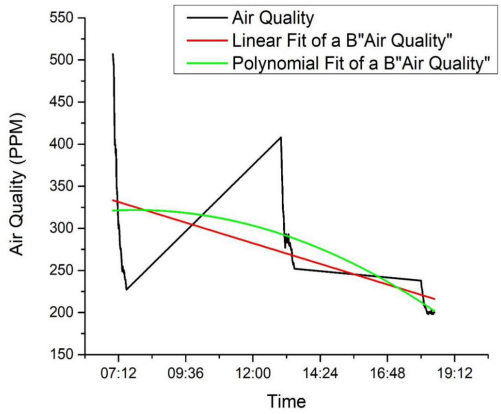

Figure 9. Graph showing the variation of PPM with time at Buddha chowk

This Table 6 below shows the standard error of linear fitting of the data obtained from Buddha chowk.

Table 6. Linear fitting of data obtained at Buddha chowk

Equation	y = a + b*x		
Residual Sum of Squares	271348.8699		
Pearson's r	–0.64166		
Adj. R-Square	0.40505		
		Value	Standard Error
Air Quality	Intercept	404.84907	17.78407
	Slope	–245.03894	31.22302

Table 7 shows the standard error of the polynomial fitting fitted using data of Buddha chowk.

Table 7. Polynomial fitting of data obtained at Buddha chowk

Equation	y = Intercept + B1*x^1 + B2*x^2		
Residual Sum of Squares	251342.58747		
Adj. R-Square	0.44258	Value	
		Value	Standard Error
Air Quality	Intercept	257.71558	58.50151
	B1	393.77057	244.62539
	B2	–605.53031	230.10503

Likewise, the analysis of the data recorded Khushi Khushi chowk at is shown in the graph below:

Figure 10 represents the graph of linear fitting and polynomial fitting fitted between air quality (PPM) and time of Khushi Khushi Chowk. It analysed the data of this location.

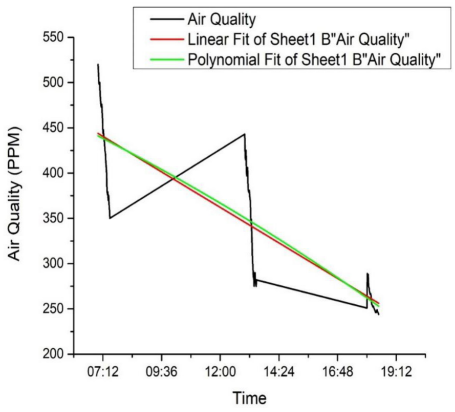

Figure 10. Graph showing the variation of PPM with time at Khushi chowk

The standard errors of linear fitting of the data obtained from Khushi Khushi chowk is shown in Table 8.

Table 8. Linear fitting of data obtained at Khushi Khushi chowk

Equation	y = a + b*x		
Residual Sum of Squares	153331.05743		
Pearson's r	–0.87192		
Adj. R-Square	0.75751		
		Value	Standard Error
Air Quality	Intercept	558.19117	13.36849
	Slope	–392.06105	23.47069

Table 9 represents the standard error of the data obtained from Khushi Khushi chowk after polynomial fitting.

Table 9. Polynomial fitting of data obtained at Khushi Khushi chowk

Equation	y = Intercept + B1*x^1 + B2*x^2		
Residual Sum of Squares	152331.02668		
Adj. R-Square	0.75633	Value	
		Value	Standard Error
Air Quality	Intercept	525.29578	45.54369
	B1	–249.23913	190.44197
	B2	–135.38151	179.1378

Analysis and comparison of data obtained from all three location are shown in graph below:

Figure 11 represents the graph of linear fitting and polynomial fitting fitted between air quality (PPM) and time all three locations. It shows the comparison of all three locations from where data are collected.

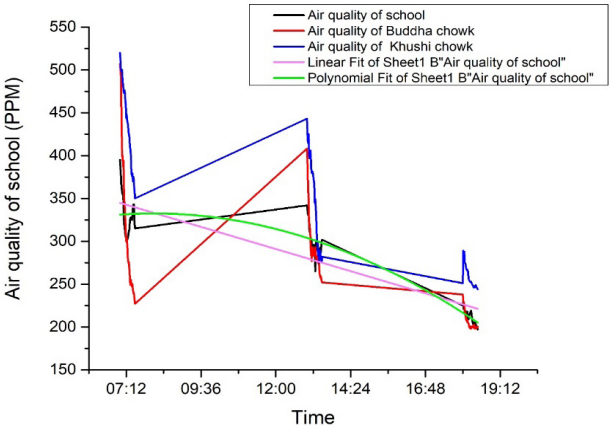

Figure 11. Graph showing the variation of PPM with time of all three locations

Table 10 shows the standard errors of linear fitting of the data obtained from all three locations .

Table 10. Linear fitting of data obtained from all three locations

Equation	y = a + b*x		
Residual Sum of Squares	51128.31124		
Pearson's r	–0.89729		
Adj. R-Square	0.80292		
		Value	Standard Error
Air Quality	Intercept	420.23025	7.71966
	Slope	–258.43197	13.55319

The standard errors of polynomial fitting obtained from data obtained from all three locations are shown in below Table 11:

Table 11. Polynomial fitting of data obtained from all three locations

Equation	y = Intercept + B1*x^1 + B2*x^2		
Residual Sum of Squares	26049.172		
Adj. R-Square	0.89844	Value	
		Value	Standard Error
Air Quality	Intercept	255.49572	18.8335
	B1	456.796	78.7527
	B2	–677.9677	74.07813

5. Conclusions

In this research, construction of "Air Pollution Monitoring System" based on Arduino Uno has been completed and measurement of air quality in PPM has been done by using the device. This "Air Pollution Monitoring System" works with a MQ 135 sensor and measures air quality of a specific location within the range of the sensor. It used Arduino Uno as a microcontroller which receives data collected by the sensor and display in the monitor as well as stored in the computer. I2C display has been used to monitored the air quality measured by the device. The device was constructed and tested.

To test the accuracy, reliability and validity of constructed device, data related to air pollution were recorded from three different locations, Basic Learning English Secondary School, Buddha Chowk periphery and Khushi chowk of Chandragiri-10, Boshigaun which lies within the southern part of Kathmandu. After collection of the data analysis of the data has been done. The data of air quality collected from these three locations have been fitted with linear line and polynomial curve using origin software. The standard error of linear fitting and polynomial fitting of air quality with respect to time has been done for the data of all three locations in the intercept.

The standard error of linear fitting and polynomial fitting of Basic Learning English Secondary School was obtained as 7.71966 and 18.8335 respectively. Similarly, the standard error of linear fitting and polynomial fitting of Buddha chowk periphery was found to be 17.78407 and 58.50151 respectively. Likewise, the standard error of linear fitting and polynomial fitting of Khushi chowk was obtained as 13.36849 and 45.54369 respectively.

In a nutshell, this device works perfectly for the measurement of air quality of a specific location within the range of sensor. The air quality of the observed locations is found to be less than 500 PPM in average. With the use of this device, the air quality of the locations that were under observations is found to be very good in average. It is found that the air quality of Chandragiri-10, Boshigaun is very good during evening time, normal during day time and a bit polluted during morning time. At last, this device works perfectly and can be used for the accurate and reliable data of air quality of specific location.

Conflict of Interest

There is no conflict of interest.

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