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Design and Implementation of an IoT Based Air Pollution Detection and Monitoring System

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***Abstract*— We live in an era of the industrial boom. With the rapid advancement of technology, day by day the number of industries and factories, which are responsible for environmental pollution are increasing rapidly. To control the pollution in the air or in an environment, continuous monitoring is necessary. But most of the existing systems are expensive and complicated. But dilatory increases in low-cost air quality monitoring systems are responsible for overall degradation. To solve this problem, we proposed an air pollution detection and monitoring system, which is simple in design, mobile, and low cost. Our proposed monitoring system embodies a device made of various gas sensors, a GSM module, a cloud server, and a mobile application. In our implemented device, one can easily access the data from the server and app to monitor the air pollution condition. Also, it consists of an alert system, which will send a notification to responsible officials if the pollution parameter exceeds the standard permissible limit. The overall cost of our implemented system is BDT 3500 (USD 40) which is lower than previously implemented systems in Bangladesh.**

Keywords—Air Pollution, Internet of Things, Android Application, Gas Sensors, Air Pollutants

I. INTRODUCTION

With the excellence of industrial establishment and rapid increase of population, air pollution is increasing day by day. The increase in industrial activities triggers increases the use of vehicles. Combustion of fuels in the different production process in the industry and vehicles produce a lot of hazardous gases in the environment. Air pollution is the reasons of many known and the acute problem of the current world which includes greenhouse effects, global warming, depleting the ozone layer, climate change and the reason of extinction of different animals and many more are endangered [1]. Due to air pollution, air is contaminating day by day which means the standard quality of air is decreasing which have negative effects on our health causing different severe diseases like lung diseases and asthma, allergic reactions and cardiac diseases [2]. Air pollution can also cause premature deaths [3]. So, air pollution must be controlled to ensure a better, green and pollution free world.

TABLE I. SHORT-TERM EXPOSURE LEVEL [6]

Substance	Workplace Exposure limits
CO_2	15000 PPM
NH_3	35 PPM
CO	200 PPM
CH_4	10000 PPM
Dust Concentration	5000 pcs/0.01cf

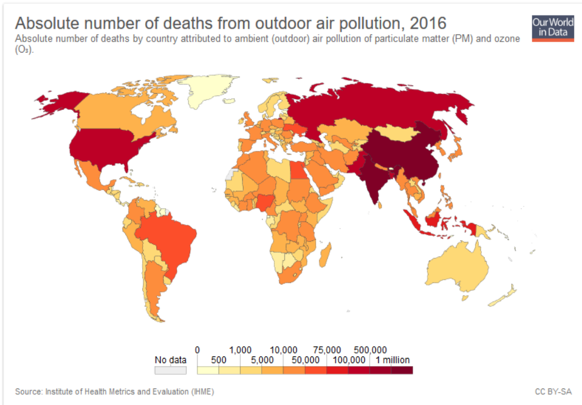

Fig. 01- Number of deaths due to outdoor air pollution [5]

The process of conventional air quality measuring is very complex, expensive and have lack of mobility [4]. So, we need a low-cost approach to continuously monitor, record, guide and control air pollution. Fig.-01 shows an absolute number of deaths from outdoor air pollution in 2016. TABLE I shows the short-term exposure level (15 minutes) of different air pollutants which can be dangerous.

In recent times there have been few studies going on air pollution monitoring system. Among them, Honicky et al. proposed a system for outdoor air pollution sensing system named N-SMART where they used sensors (CO sensor, NO_X sensor, temperature sensor, and Bluetooth module) and a cell phone was used to collect the raw air pollution data. It can be noted that the system concentrates only on sensing part [7]. Hu et al. designed a system to attain climate condition monitoring using VSN (Vehicular sensor node). A CO_2 sensor was attached outside the vehicle to record and monitor the CO_2 concentration only [8].

A WSN based air quality detecting techniques proposed by Liu et al. which includes a set of sensor nodes, a gateway and a centralized control system provided by the LabVIEW program. In this system, only CO is sensed [9]. Hasenfratz et al. designed an air quality sensing and monitoring system using smartphones where a power saving and less expensive portable air pollution detecting system for outdoor O_3 sensing, named 'Gas Mobile' was developed.

Deavarakonda et al. designed a Vehicular Sensor Node based mobile air pollution sensing and measuring system named MSB which comprises only two basic sensors (CO sensor and PM sensor). The system is able to collect data with a GPS that provides time and location information and a cell phone for data transfer [11]. Kim et al. developed an air pollution monitoring system to collect only the data related to the temperature, relative humidity, particulate matter and CO_2 [12].

An environmental pollution detection system has been reported in respect of Bangladesh by a group of researchers [13]. They proposed a system with dust sensor, noise sensor and a gas detection sensor to monitor environmental pollution. The cost of the proposed system was USD45.

All the system proposed above have few lacking such as some system detects only one or two parameters, few systems lacked the mobility features and few could not measure the pollutants in PPM concentration. An alarm system to alert people was also absent in most of the cases.

Use of web-based monitoring or android application-based monitoring systems have increased different systems acceptability and usability due to remote monitoring provision. Many systems used android based application or web-based application system to improve their monitoring systems [14, 15]. Environmental pollution monitoring systems can also be utilized efficiently if we use android application-based monitoring systems which would not only improve monitoring system but also ease critical decision making from remote places.

In our paper, we proposed a system that will provide good air quality data and comprises of various gas sensors, GSM module, cloud server, and a mobile application. We have designed and built a low-cost air pollution measurement and monitoring system which detects and measures data with good accuracy. The device has unique features such as- mobility, extensibility and user-friendly. A combination of display, server and mobile application in case of data monitoring gives it a balanced and robust composition in the field of data monitoring.

II. SYSTEM OVERVIEW

A. System Design and Methodology

Overview of the proposed air pollution detection and monitoring system is shown in the following Fig. 02. Air pollution data are collected with the help of a different gas sensor. The acquired data are then processed by Arduino microcontroller. After processing Arduino send data to a server where data are updated and recorded continuously. The real-time air pollution data can also be monitored with the help of an android application. If any pollution data exceeds threshold limits the system alarms the responsible authority.

B. System Components

Our proposed monitoring system consists of two parts: Hardware Part and Software Part. Those components which make these two parts are described in the following sections.

1) Hardware Section:

The hardware section can be divided into two sub-divisions: Data Acquisition; Data Transmission. The data acquisition part consists of different sensors to acquire pollution data. In the proposed system MQ-135 module is used in air quality control for sensing and measuring CO_2. Ammonia is measured using MQ-135. MQ-4 CH_4 gas sensor is deployed in this system to measure the concentration of CH_4 gas in the air. The MQ-7 gas sensor measures the concentration of CO gas in the air in our system. HSM-20G humidity senso rand an LM35 temperature sensor are used in our system to measure humidity and temperature, respectively. A dust sensor is also included in our system to measure the amount of dust present in the air. The Data Transmission is necessary to send acquired data to the server. SIM800L module is implemented in our system to send data to the server.

2) Software Section:

To monitor the data a mobile application is built in Android platform using JAVA language that includes json.org library which allows processing and creating JSON files.

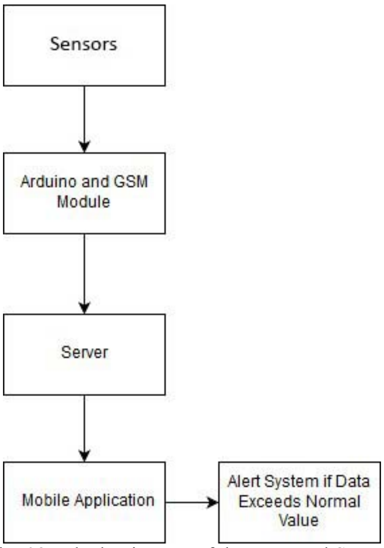

Fig. 02- Block Diagram of the Proposed System

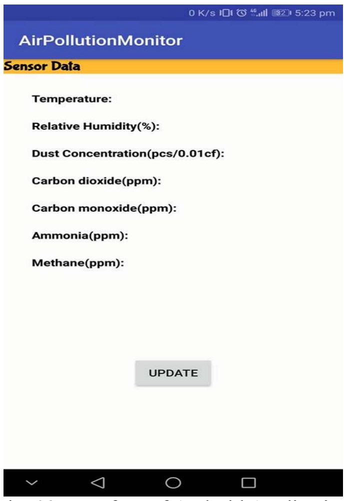

Fig. 03- Interface of Android Application

In our system, Server collects data from the GSM module and the data can be collected from the server in JSON format. The API build with Android platform can extract the data from JSON data (known as JSON parsing) and show the Data on the Android application. The User Software has been developed using JAVA framework as it offers easier integration with Android smartphone and is used to monitor the air pollution and to notify the related industry if gas concentrations exceed the threshold level. Fig. 03 shows the interface of the android application.

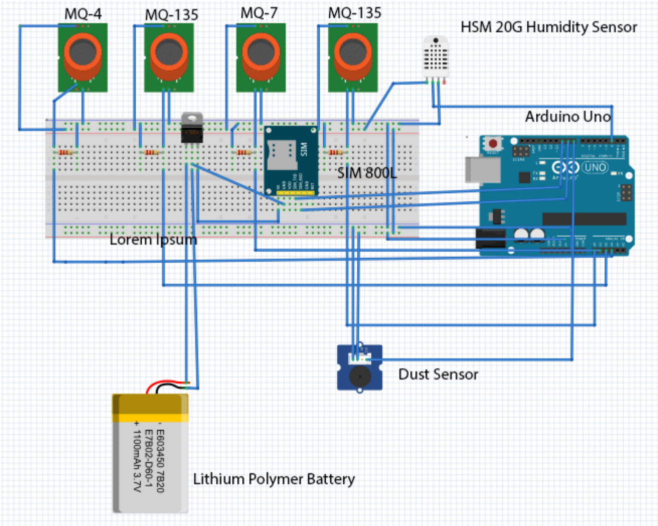

Fig. 04- Designed Model of Proposed System

C. Circuitry Design and Implementation

In Fig. 04 shows the designed model of our proposed system. After designing the system, we connected all the calibrated gas sensors, temperature and humidity sensors, and dust sensor and additional power conversion equipment and completed the implementation of our proposed project. The final implemented circuit diagram of our project is shown in Fig. 05.

III. RESULT AND DISCUSSION

After the implementation of the final circuit, we measured data in an Industrial Area which is Chittagong Power Plant situated at Raozan, Chittagong. The data we measured in the industrial situation is presented in Fig. 06, Fig. 07, Fig. 08, Fig. 09, Fig. 10, Fig. 11 and Fig. 12.

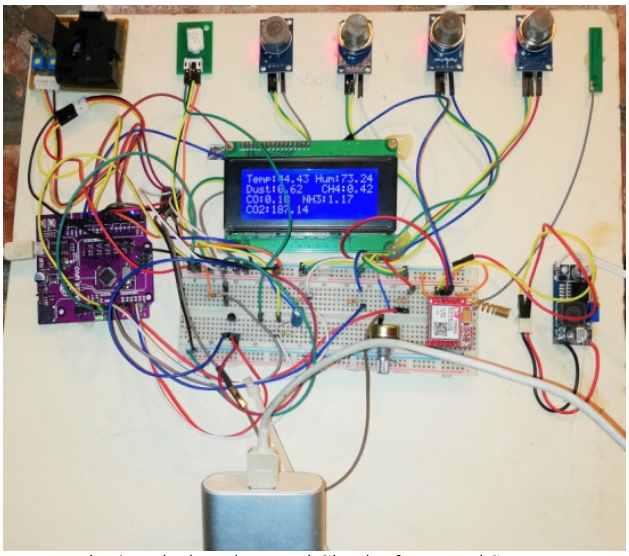
Fig. 05- Final Implemented Circuit of Proposed System

Fig. 06 shows the dust concentration (pcs/0.01cf) measured in the industrial situation. The maximum amount of dust is measured around 8200 pcs/0.01cf which means at some point of the process, the air gets polluted with dust particles beyond limit (5000 pcs/0.01cf).

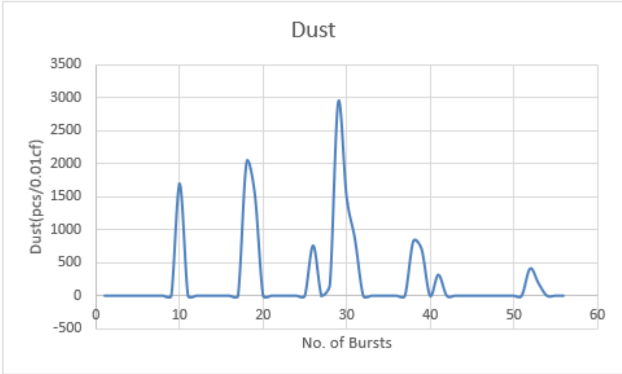

Fig. 06- Dust concentration measured in Industry

Fig. 07 depicts the CO_2 concentration in air in ppm. The data is around 200 to 700 ppm. The maximum amount of CO_2 is within the safety limit.

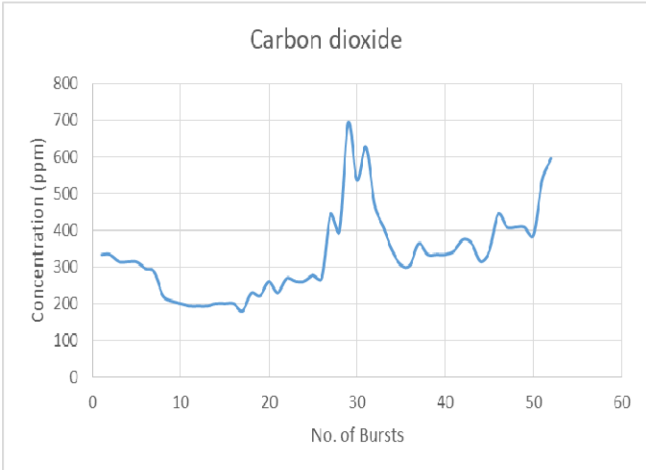

Fig. 07- CO_2 concentration (ppm) measured in Industry

In Fig. 08 and Fig. 09, amount of methane and humidity are presented which was collected from air. The maximum humidity recorded was 75%. The amount of methane is also with in the controllable limit.

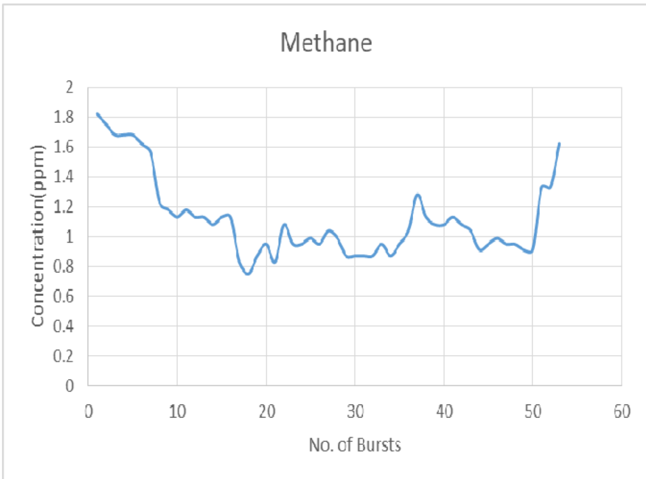

Fig. 08- CH_4 concentration (ppm) measured in Industry

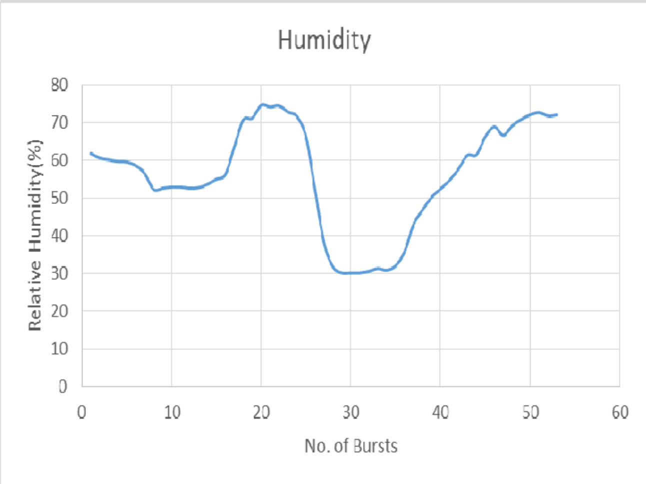

Fig. 09-Relative Humidity (%) measured in Industry

Fig. 10 shows the concentration of CO present in the air, whereas, Fig. 11 portrays the temperature in degree Celsius of the surrounding area. The amount of CO in air is below 0.3ppm. The amount of CO available in air was harmless.

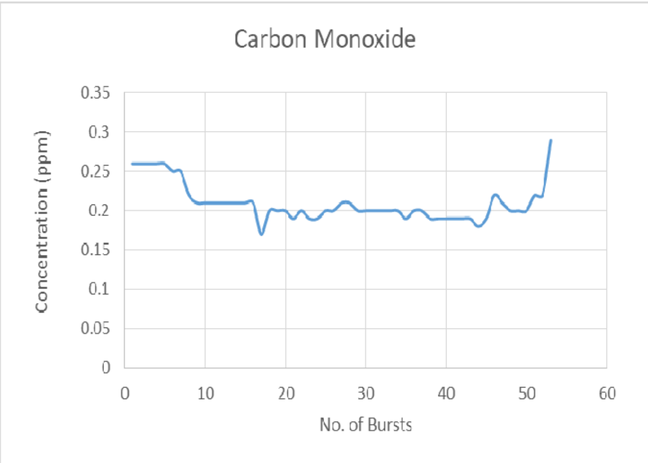

Fig. 10- CO Concentration (%) measured in Industry

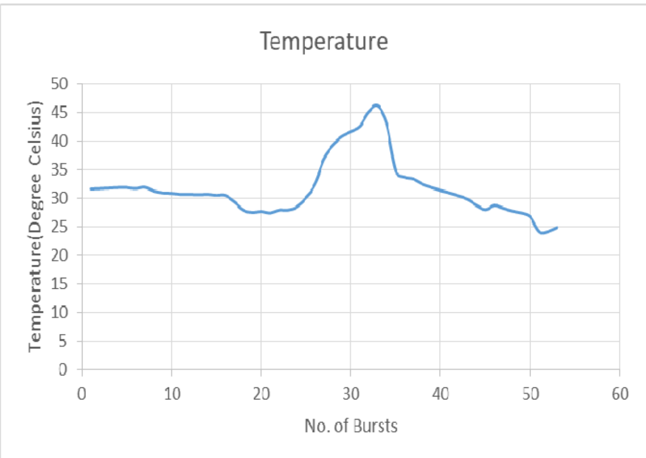

Fig. 11- Temperature (°C) measured in Industry

The present amount of ammonia in air is delineated in Fig. 12. The maximum amount of Ammonia present in the air is 9 ppm which is below the maximum allowable limit 35 ppm.

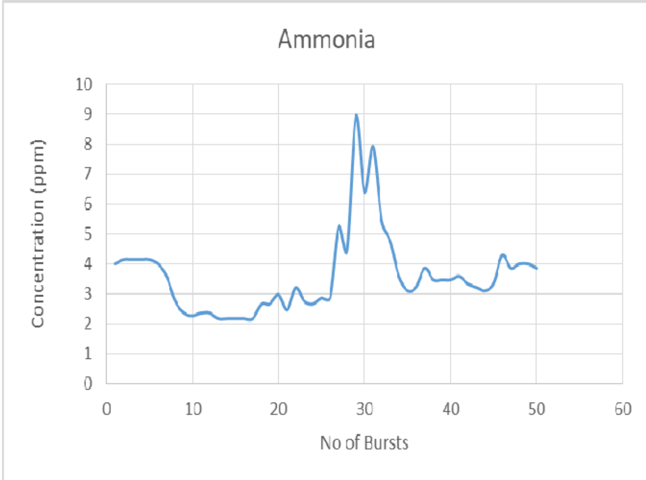

Fig. 12- Ammonia Concentration (%) measured in Industry

Fig. 13 portrays a mobile application interface with acquired data. The data can be seen continuously with the help of the android application which can help concerned persons to monitor the whole situation from remote location. These data can be used to control the system from distant location.

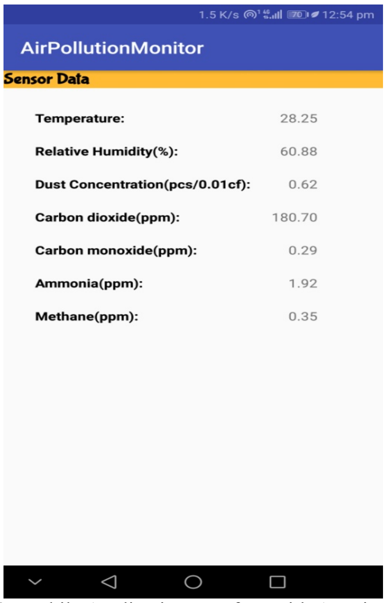

Fig. 13- Mobile Application Interface with Acquired Data

In our study, we also found that GSM modules are less reliable in scenarios where the area is too much confined within the Industry. To remove this error Wi-Fi modules can be used but it would strip away the feature of mobility. In our study, we have used six types of sensors. But, in our proposed system there are opportunities to add more sensors to acquire various types of pollution data as requires, which gives our system the edge of extensibility. Our device collects data continuously and stores those data in a server. These data can be trained with machine learning algorithms to predict the future pollution or growth of the industry. Thus, giving us the opportunity to take proper steps to reduce pollution and improve the condition of the environment.

IV. COST ANALYSIS

The cost of our device is BDT 3500 (USD 40). The breakdown of cost is presented in TABLE II. Our device costs lower than device [13] which was previously implemented in Bangladesh. The proposed system by [13] cost USD45, on the contrary our system only cost USD40 with more gas sensors. This indicates that our system is much more cost effective than previously implemented system for Bangladesh.

TABLE II. COST SUMMARY OF PROTOTYPE

Sl.	Name	Quantity	Price (BDT)
1	Arduino UNO	1	400
2	Grove Dust sensor	1	965
3	MQ-4 Gas sensor	1	130
4	MQ-135 Gas Sensor	2	330
5	MQ-7 Gas Sensor	1	350
6	HSM-20G Humidity Sensor	1	450
7	SIM 800 SM Module	1	400
8	20x4 Alphanumeric LCD Display	1	280
9	LM 35 Temperature Sensor	1	50
10	Miscellaneous		150
	Total		3455

V. CONCLUSION

In this paper, we have successfully designed and implemented a low-cost air pollution detection and monitoring device which can continuously monitor air pollution data. The price of this system is only BDT 3500 (USD40) which gives it an edge over existing modules. The system has features such as extensibility, mobility, and robustness which gives it more credibility over existing systems that are being used as prototype in various applications. We think our implemented system would be vital to design much larger air pollution monitoring system with low-cost and simplicity.

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