Monitoring Air Quality of Dhaka using IoT: Effects of COVID-19

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***Abstract*— Air pollution and COVID-19 both are the most provocative issue nowadays. Air pollution holds a dangerous impact on the COVID-19 issue as well as human health. The urban cities like Dhaka are under stress to remain habitable. With the huge density of transportation and population, air quality index is to be monitored minutely and the impact of the COVID-19 pandemic is to be observed. It is required to develop an Internet of Things based remote monitoring system to observe the air particularity in the different areas of the Dhaka city and make a comparison between the before and during the COVID-19 Pandemic. The platform aims to track out the concentration of gases in the Dhaka City like carbon monoxide (CO), nitrogen di-oxides (NO_2) on real-time that provides air quality index (AQI). Using Arduino based Node MCU and the sensors are to detect substantive conditions of gases. ESP-32 Wi-Fi module is used to send the data to the server so that it can be accessed from anywhere. The data is taken before and during COVID-19 period with the developed IoT platform. It shows the difference between the CO and NO_2 emission on the impact of the pandemic with the measured value. This study will help us to make further decisions and action regarding air pollution.**

Keywords*— Air Pollution; COVID-19; Internet of Things; Dhaka City; Node MCU*

I. Introduction

Air pollution is one of the biggest problems for every developed or developing country. Especially in urban areas of developing countries where industrialization is taking place, health problems related to air pollution have been growing at a faster rate. Because of air pollution, up to a hundred thousand lives are going out per year in the United States and three hundred thousand in [l]. For instance, deforestation for recent migration has threatened the environment due to COVID-19 pandemic that is defining the area in the southeast part of Bangladesh, the CO emission increases [2]. Besides, the world is going through the greatest challenge due to COVID-19 pandemic that is defining a great global health crisis in the era. Many people have been dead and many are seriously affected.

Moreover, Bangladesh is one of the most densely populated countries and Dhaka is the capital city of Bangladesh. Very few cities in Asia have the annual population growth rate like Dhaka [3]. Here, the annual rate of the population growth is 1.4% [4]. The city is badly affected by COVID-19. Around 25.6 thousand people affected and 3.4 thousand people died off in Bangladesh [5]. Researchers have found a relation between AQI and COVID-19 [6]. Here, we tried to figure out the amount of the most harmful gases like CO and NO_2 along with the status of AQI. The Air Quality Index (AQI) is being calculated based on air substances like CO and NO_2 compounds that devour opposing control in the human health and environment. The environmental data can be collected remotely also using RADAR [7, 8], Satellite [9], ionosonde [10] and IoT sensors [11]. In this study, the data was collected on January 6, 2020. The data is also compared with the AQI website maintained by the US embassy.

Internet of Things (IoT) is an interconnection of sensing devices, accumulation and transference of data using the internet without any human intervention for making the remote monitoring system where devices can be connected with machine-to-machine (M2M) communication [12]. Environmental conditions monitoring in homes have been inspected in [13]. The author proposes a structure to monitor temperature, humidity and light intensity, based on a combination of distributed sensing units, information system for data accumulation, and adjudication and context awareness. Various monitoring systems have been proposed recently for environmental pollution monitoring. A monitoring system is developed that gives the concentration of carbon-di-oxide of remote areas in [14]. The system also responds to temperature, humidity and light intensity of the outward monitoring area. An urban CO_2 monitoring system presented in [15]. Around a hundred square kilometres of an urban area is covered by the system. A WSN based system is made for indoor and outdoor air quality monitoring in [15-16]. Satellite remote Sensing Techniques can be useful to monitor Air Quality [17].

There was no study of the Air Quality Index for Dhaka City in the earlier time and hence we have planned to work for making the IoT platform to measure the air quality based solution on CO and NO_2 gases. Therefore, a high fidelity air quality index-monitoring device at a low cost has to be fabricated using which data at each second can be accumulated, transferred and analysed the data to cloud storage using the device. This paper examines the infrastructure, information processing, and exceptions of sketching and introduces a compact sensing system for real-time air quality monitoring platform-using microcontroller.

II. Structural Architecture

According to the fundamental model, IoT architecture has three layers; the system is made of the sensing layer, network layer and application layer. There are many and different architectures have been proposed which support the four-layer architecture [18]. Here, We have made the structure based on three layers of architecture.

A. IoT Structure

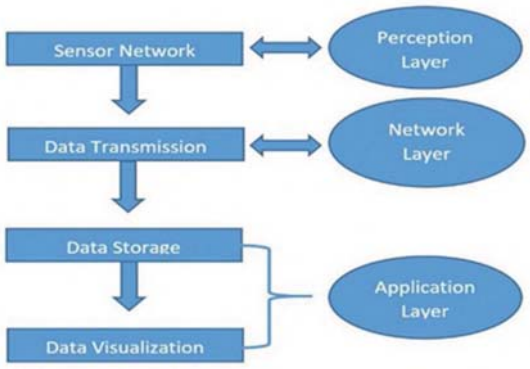


Fig. 1. IoT three-layer Structure

a) Perception layer: The perception layer is the substantive layer, which has sensors for collecting information about the environment and surrounding. It senses some real parameters or identifies other objects from the environment [18-19]. In this project, we use Node MCU with two semiconductor gas sensors MQ-7 and MQ-135 according to the requirement of air quality measurement to collect and transmit the measured data to the server. We program the ESP-32 inbuilt Node MCU as a central controller and Wi-Fi module as well.

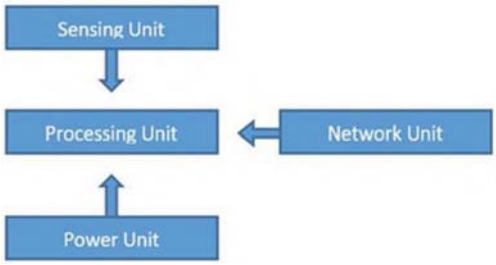


Fig. 2. Perception Layer of IoT

b) Network layer: The network layer is accountable for bringing all the peripherals like the intelligent sensors, network devices, and servers under an umbrella. It is also called the transmission layer and acts as a bridge between the perception layer and application layer, which is used for transmitting and processing the data, gathered by sensors [18-19]. But here the wireless medium is used as a network layer. Node MCU, which has a Wi-Fi module, is used as the wireless access medium.

c) Application layer: The application layer is the final state of IoT, which is accountable for providing services to the user. It prescribes several applications for the deployment of the Internet of Things [18]. Application layer defines all applications that use IoT technology. The applications of IoT can be smart homes, smart cities, smart health, animal tracking, etc. The services might be asymmetrical for every application as the dependency on the sensor gathered information [19]. The whole system is designed mainly to process and analyse the air pollutant data like CO and NO_2 gases. Then, the air quality can be evaluated and then the trend of the air quality can be predicted. Here, we have used MS Excel to visualise the data.

Fig. 3. Application Layer of IoT

B. Wireless Sensor Network (WSN)

Wireless sensor network, consisting of sensors can be defined as automated and fundament-less wireless networks for monitoring surroundings. Every sensor can detect and gather data from the periphery using wireless technology. WSN is used for remotely monitoring the low-frequency data [20]. The WSN is essential to design the framework otherwise; the customary wired design will be costly and inconvenient. In the project, ESP-32 is used to create the Wireless Sensor Network. ESP-32 has higher processing and to handle WSN than any other WSN module [20].

Fig. 4. ESP-32

C. Firebase Server

Measuring data in a system with sensors is huge and versatile. Therefore, having high data storage or server and processing capacity is essential. Firebase is an open-source and very popular cloud-hosted storage server. Firebase is acquired by Google, which is widely used for APK developing [21]. In ours, Firebase Real-time Database is used to allow on a per-user basis data control access using conditions, which will help people to know about the status of pollutants in the air.

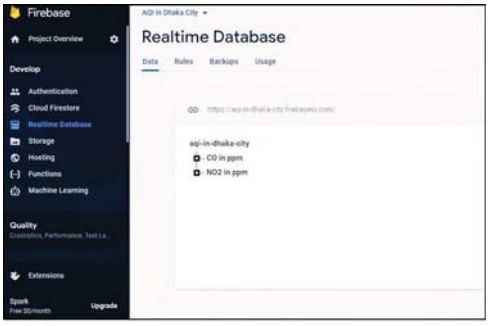


Fig. 5. Firebase Console

D. Gas Sensors

Sensors can be called 'Things' of the IoT system. Collecting data from the environment is the main purpose of the sensors. As we wanted to make a low-cost device, the low-cost MQ semiconductor gas sensors were being used. The proper calibration should be done to get an accurate measurement with the method of cycle high and low temperature, which is done, in two steps. Firstly, to find the initial zero value of sensors and secondly, to determine the rhythm of the sensors [22]. Here, we used two sensors named MQ-07 and MQ-135. The sensors are operated in 3.3-5 volt and calibrated in pure air in the morning. We have observed one of the problems with the sensors that at least constant 5

Volt and 1 Amp should be given for 72 hours to make the sensors work properly. The details of the sensors are tabulated in the following table.

TABLE I. SENSOR DETAILS [22]

Sensor	Gas	Description	Range
MQ-07	Carbon Monoxide	Sensing CO concentration in the air. It can detect CO-gas concentration anywhere from 20 to 2000 ppm.	0-100(No effect) 100-800 (Risky) 800-2000 (Very high)
MQ-135	Air Quality	Responsive to a wide scope of harmful gases like alcohol, thinner, formaldehyde and so on.	0-500 (Normal) 500-1500 (Risky) 1500-2000 (Very High)

E. Node MCU

Node MCU is an open-source Arduino based firmware or IoT platform. It can be said within C++/C or Lua programming language based IoT prototype [23]. This is developed as ESP-32 Wi-Fi chip. ESP-32 can be used for another application processor through its Wi-Fi networking solution. Having heavy processing capabilities with sufficient storage, it runs with minimal loading time through its GPIOs (General Purpose Input/output) with the sensors. Due to its low cost and high features, it has become an ideal module for the Internet of Things (IoT). The problem with the Node MCU is that it has only one analog pin A0 [23]. So, the two analog sensors cannot be used simultaneously. That is why we have taken one by one.

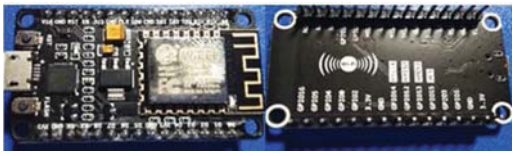


Fig. 6. Node MCU

F. Power Source

We have used an RPi battery adapter to power up the Node MCU. There are many ways to give power to the Node MCU [23]. Using USB Cable, an AC to DC adapter plugged into the barrel connector, 5-volt input, batteries more than 5 volts, a battery shield.

Fig. 7. Power Source

III. WORKFLOW AND PROCEDURE

In this section, the process of work is going to be discussed gradually. A comprehensive workflow can be visualised.

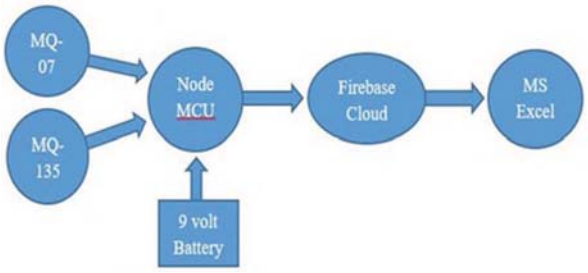


Fig. 8. The workflow of the process

The fundamental mechanism of this air quality monitoring system is shown in Fig. 8. There are two sensors on this system such as MQ-07, MQ-135. Node MCU is used as a central processing unit (CPU) to handle the data accrued from sensors through (I/O) pin. ESP-32 is used as a Wi-Fi Module, which is embedded with Node MCU. Then those data are uploaded directly to the Firebase server platform and network access supported by Wi-Fi adapter.

Fig. 9. Wi-Fi Adapter

Then the data has been moved from firebase server to MS excel. After that, statistical analysis like moving average, standard deviation, the distribution function of the collected data has been done.

A. Sensor Interface with Node MCU

Node MCU is a kind of Arduino based microcontroller. It is a board, which consists of ESP8266 Wi-Fi-enabled chip, and this is widely used in transferring the data. As remote access of data is essential in this project. Therefore, we have used Node MCU version 2, built with Xtensa LX106 32-bit, I2C pins, 16 general-purpose input-output pins (GPIO) and many other features. The board can be powered with 3.3-5 volt. [23].

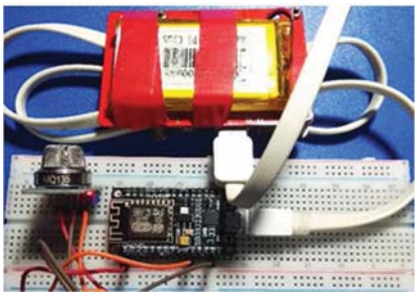


Fig. 10. MQ-135 Sensor with Node MCU

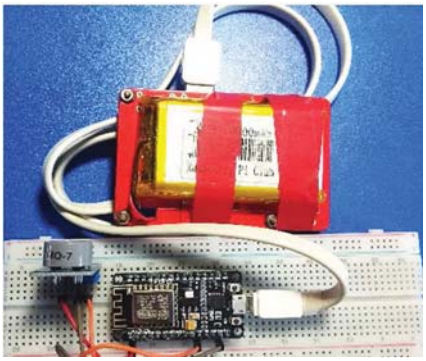


Fig. 11. MQ-07 Sensor with Node MCU

Node MCU acts as a gateway to the cloud server. In IoT, a gateway is a system that connects the collected data to the cloud. Moreover, Node MCU has four pins built-in for Serial Peripheral Interface (SPI) communication [23]. The sensors must have to be connected directly or by wire with the GPIO pins of Node MCU. Then after setting up the Arduino IDE, the library ESP8266 should be installed in the Arduino IDE to write the code for the Node MCU. MQ-07 and MQ-135 sensors should be interfaced by code with the Node MCU so that the collected data can be processed and sent to the server.

B. Collecting Data and Sending to Firebase

The most essential part is the collection of data from the surroundings. We have collected the data from the different parts of Dhaka city to know about the real-time AQI before and after the lockdown. The sensors collect the data from the environment and send it to the Node MCU. Then, Node MCU along with ESP-32 upload the data to the firebase online server. A library named 'Firebase RTDB' must be installed in Arduino IDE [21]. Once the data is uploaded, then the server is responsible for its security. In firebase, without authentication, none is allowed to access the data. To access the database a valid email sign is required. The data is stored as a JavaScript Object Notation (JSON) file in Firebase. After storing the data as JSON in the server [24], it is easily convertible to MS excel or google sheets and do the statistical analysis.

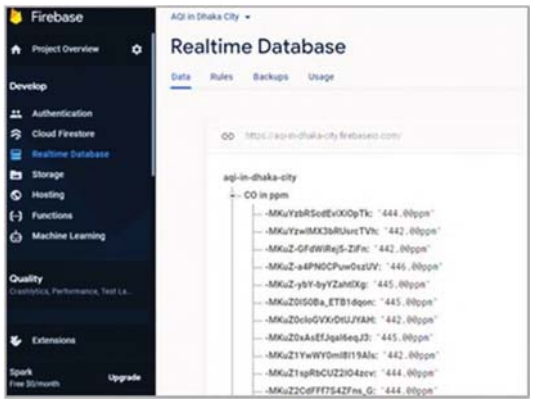


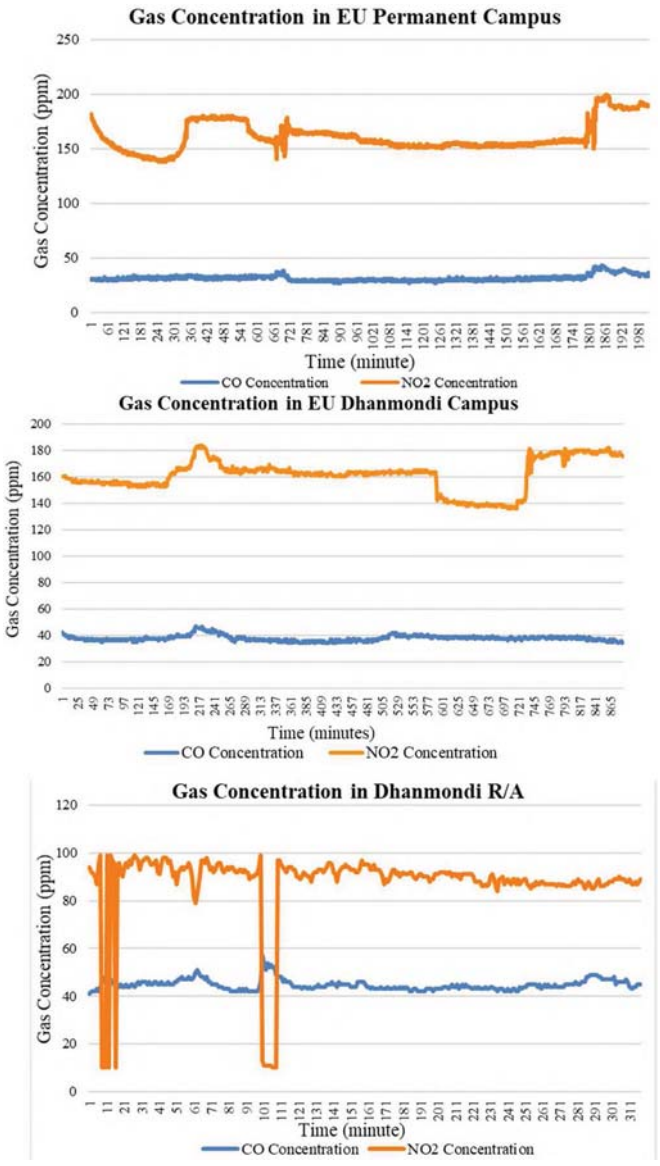
Fig. 12. Real-Time Database on Firebase

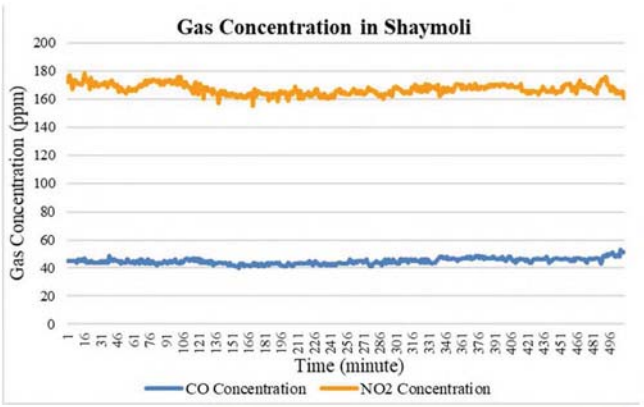
IV. Experimental Analysis And Result

In this section, we have shown the findings of our work. The IoT device has taken different places in Dhaka City to measure the AQI. We have gone to so many places like Eastern University Campus, Dhanmondi Road No-5, Shyamoli, and the University of Dhaka Campus and so on. Due to the COVID-19 pandemic situation, the people of Dhaka have faced the lockdown for at least six months. Therefore, we have decided to make a comparison between the AQI before and during the lockdown period (Fig. 15). The various kinds of statistical analysis like moving average, correlation coefficient, standard deviation and frequency distribution (Fig. 14) of the collected data have been done. This analysis will help to smooth out the noise of random outliers and emphasize long-term trends of the collected data.

A. Gas Concentration in PPM of different places on Dhaka City

After measuring the amount of CO and NO_2 gas respectively with MQ-07 and MQ-135, the AQI value is being calculated based on the measured value of CO and NO_2 Gas using the AirNow AQI calculator [25]. After calculating the AQI, the status of the AQI value is also measured according to the level.





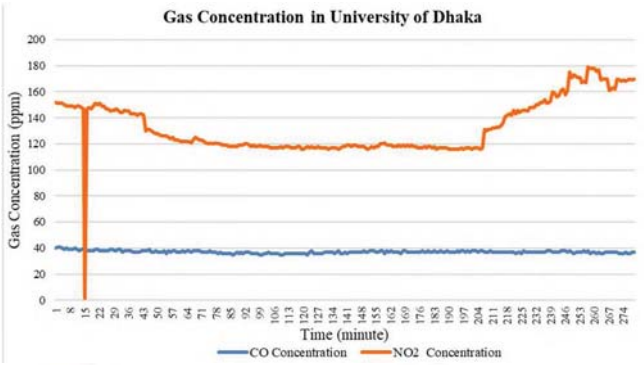
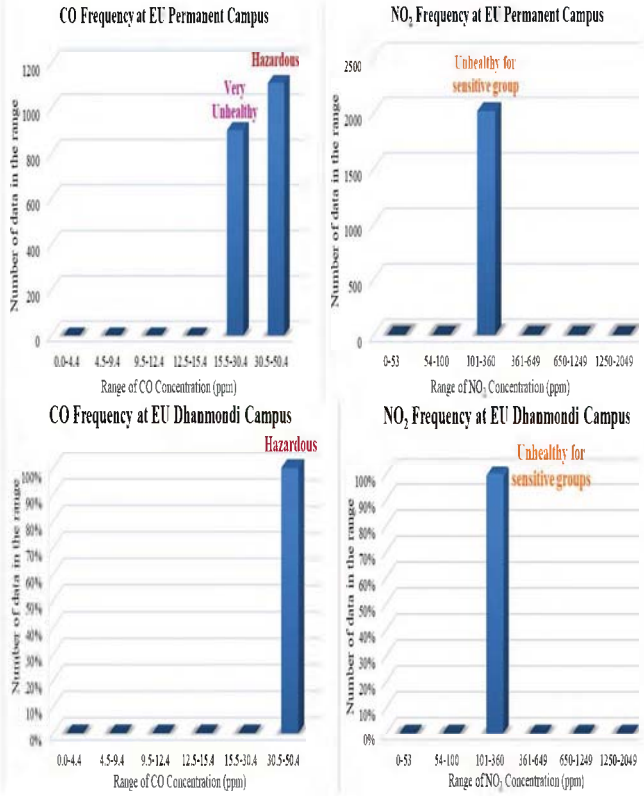


Fig. 13. CO and NO_2 Gas concentration in PPM

B. *Statistical Analysis of the collected data*

Here, the frequency distribution, done according to our collected data have been shown (Fig. 14). The status of AQI according to CO gas emission of the different places of the city are mostly hazardous and according to NO_2 gas emission, it is mostly unhealthy for sensitive people.



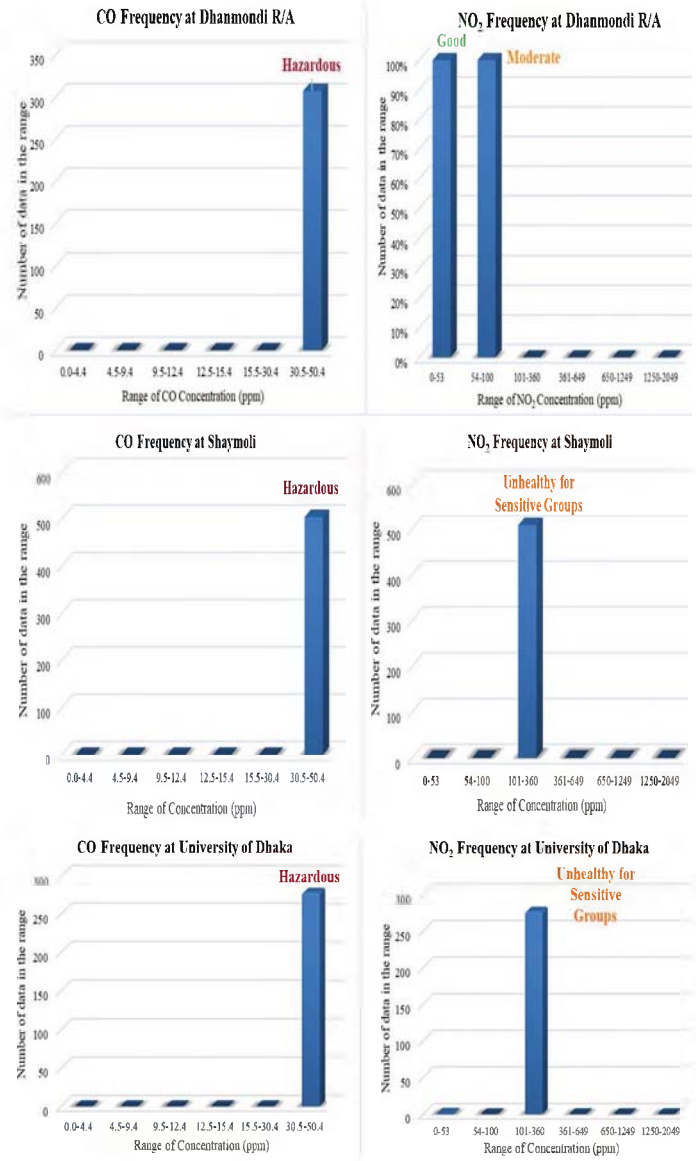


Fig. 14. Frequency Distribution of collected data

C. *Effect of COVID-19 on Gas Emission:*

In this section, the difference between the emission of CO and NO_2 gases, before and during lockdown has been shown (Fig. 15). The developed IoT based device has been kept ON for 15 days before the lockdown (February 10, 2020) and during the lockdown (March 20, 2020). Here, the emission of gases was increased during the lockdown in Dhaka. The blue line indicates the concentration of two gases before COVID-19 and the red line indicates the concentration of gases during COVID-19. It can be seen that the line graph (Blue) of NO_2 remained constant and its magnitude was higher in time of before COVID-19 compared to during COVID-19. On the other hand, the concentration graph of CO has been increased during COVID-19 period compared to before COVID-19. Moreover, there are some abrupt changes and spikes can be seen during COVID-19 period for both of the gases. This might be happened due to the daily variations, which has been discussed in the next section.

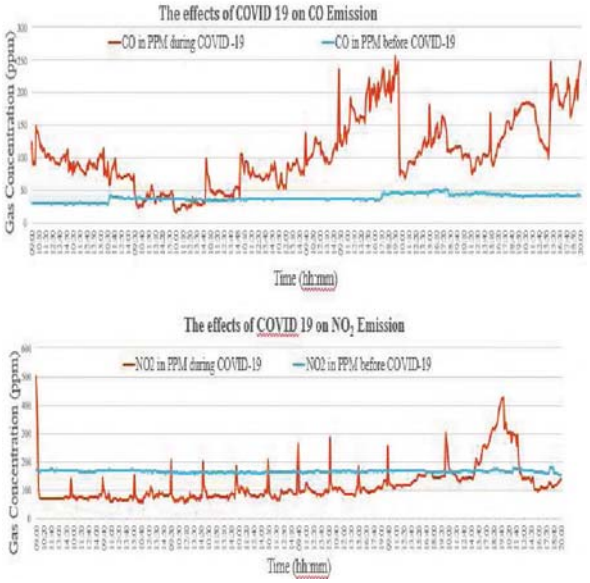


Fig. 15. The effect of COVID-19 on CO and NO_2 emission

V. Comparison and Result

We have compared our data collected by sensors with the US embassy data collected from the AQI website [26] on the same day. The data show both values of the CO and NO_2 are higher than the US embassy data. Nevertheless, the covariance and correlation coefficient values are 248.6 and 1 respectively. This indicates the high correlation between the two different measurements/instruments.

TABLE II. Comparison of Data

January 6, 2020

	Shyamoli	EU PC	Dhanmondi Lake	EU DC	DU	Average value from Sensors	Avg value from AQI source
CO	44.96	31.33	44.79	37.86	37.17	39.94	12
NO_2	166.94	161.38	86.85	112	107.4	102.08	28
time	9:00	11:00	17:00	17:30	18:00		

We also plotted the two environmental indicators concerning time (Fig.16). This indicates the value of NO_2 is high in the morning, goes down in the daytime and increases in the evening. This pattern is identical with the standard measurement.

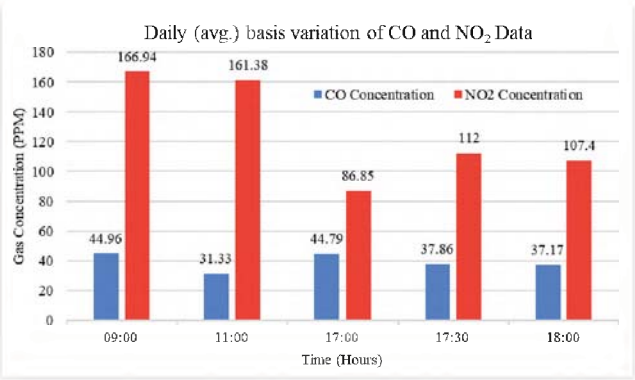


Fig.16. Daily variation of CO and NO_2

VI. Discussion and Conclusion

The paper presented the air quality monitoring of Dhaka City and the impact of the current pandemic on AQI. Researchers from India [27] and Bangladesh [6] have studied the relation between CFR (COVID-19 Fatality Rate) and AQI. However, air quality monitoring of Dhaka city using IoT during and before the pandemic has not done before. The graphs are plotted in the MS Excel which can be understood by mass people. This project has already been implemented in Eastern University Premises to know about the AQI in real-time. The government of Bangladesh can utilize these findings to understand the relation between air pollution and epidemic disease. This study can also help to formulate new policies for minimizing the harmfulness of the epidemic diseases like COVID-19. It can be beneficial for the researchers who are working on understanding the perceptible relationships of the COVID-19 with pollution and its associated variables. The study will encourage implementing IoT in the real-time pollution monitoring system and to do further research.

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References

[1] P. K. Streatfield, K. Z. Ahsan, "Population Challenges for Bangladesh in the Coming Decades," *Journal of Health, Population and Nutrition,* vol. 26, no. 3, pp. 261-272, Sep. 2008.

[2] S. A. Hoque, M. M. M. Ahmed, and M. M. I. Bhuiyan "Investigating rapid deforestation and carbon dioxide release in Bangladesh using geospatial information from remote sensing data," *Ecocycles,* vol. 5, no. 2, pp. 97-105, Dec. 2019.

[3] F. Caiazzo, A. Ashok, I. A Waitz, S. H. L. Yim and S. Barrett, "Air pollution and early deaths in the United States. Part I: Quantifying the impact of major sectors in 2005," *Atmospheric Environment,* vol. 79, pp. 198-208, May 2013.

[4] A. Dewan and R. Corner, Dhaka Megacity: Geospatial Perspectives on Urbanisation, Environment and Health, Netherlands: Springer, Sep. 2013.

[5] Worldometers, "COVID-19 Coronavirus Pandemic," 08 August 2020. [Online]. Available: https://www.worldometers.info/coronavirus/. [Accessed 08 Aug. 2020].

[6] M.S. Hassan, M. Hossain, S.M. Tanu, and M.F. Tareq & M. B. Doza & K.A. Rabbani, "Spatial Relationships between COVID-19 infection rates and Air Pollution, Geo-Meteorological and Social

Parameters in Dhaka, Bangladesh," 30 June 2020. [Online]. Available: https://www.researchsquare.com/article/rs-39091/v1. [Accessed 04 Nov. 2020].

[7] S.A. Hoque and F. fenrich, "A New Technique for Understanding Magnetosphere-Ionosphere Coupling Using Directional Derivatives of SuperDARN Convection Flow," *Journal of Astrophysics and Astronomy,* vol. 39, no. 70, pp. 1-13, Nov. 2018.

[8] S. A. Hoque and F. R. Fenrich, "Temporal Evolution of the Open-Closed Field Line Boundary Determined Using Superdarn Velocity Gradients," American Geophysical Union, AGU Fall Meeting 2011, Dec. 2011.

[9] Md Bhuiyan and S.A. Hoque, "Flood Monitoring and forecasting using synthetic aperture radar (SAR) and meteorological data: A case study," *Malaysian Journal of Fundamental and Applied Sciences (MJFAS),* vol. 16, no. 3, pp. 300-306, Jun. 2020.

[10] S.A. Hoque, "Improvement of B2bot correction factor for NeQuick 2 during the high solar activity at Saint Croix," *Journal of Advanced Research Design,* vol. 27, no. 1, pp. 19-26, Dec. 2016.

[11] S.A. Hoque, and T. Ahmed, "Adapting the NeQuick 2 model to GPS derived TEC data at a given location," *AIUB Journal of Science and Engineering (AJSE),* vol. 15, no. 1, pp. 135-142, Aug. 2016.

[12] Kelly, Sean and Suryadevara, Nagender & Mukhopadhyay, S.C, "Towards the Implementation of IoT for Environmental Condition Monitoring in Homes," *IEEE Sensors Journal,* vol. 13, no. 10, pp. 3846-3853, Oct. 2013.

[13] Perwej, Yusuf and Haq, Kashiful and Parwej, Firoj & M., Mumdouh, "The Internet of Things (IoT) and its Application Domains," *International Journal of Computer Applications,* vol. 182, no. 49, pp. 36-49, Apr. 2019.

[14] X. Mao, X. Miao, Y. He, X. Li and Yunhao Liu, "CitySee: Urban CO2 monitoring with sensors," in *Proceedings - IEEE INFOCOM*, USA, 2012.

[15] H. Yang, Y. Qin, Hui Ci, "Online Monitoring of Geological CO2 Storage and Leakage Based on Wireless Sensor Networks," *IEEE Sensors Journal,* vol. 13, no. 2, pp. 556-562, Feb. 2013.

[16] O. Postolache, J. M. D. Pereira, P. S. Girão, "Smart Sensors Network for Air Quality Monitoring Applications," *IEEE T. Instrumentation and Measurement,* vol. 58, no. 9, pp. 3253-3262, Oct. 2009.

[17] S.A. Hoque, "Satellite Remote Sensing Techniques for Landslides Detection and Mapping: A case study from Manikchari, Chattogram," in *Gobeshona 6, The Gobeshona Annual Conference 2020, ICCCAD, Independent University*, Dhaka, Bangladesh, Jan. 2020.

[18] P. Sethi, S. R. Sarangi, "Internet of Things: Architectures, Protocols, and Applications," *Journal of Electrical and Computer Engineering,* vol. 2017, no. 1, pp. 1-25, Jan. 2017.

[19] M. Burhan, R.A Rehman, B. Khan B.S Kim, "IoT Elements, Layered Architectures and Security Issues: A Comprehensive Survey," *Sensors,* vol. 18, no. 9, p. 2796, 2018.

[20] Y. Li and M. T. Thai, Wireless Sensor Networks and Applications, Shanghai, China: Springer, Jan. 2008.

[21] A. Alsalemi, Y.A. Homsi, M. A. Disi, I. Ahmed, F. Bensaali, A. Amira, and G. Alinier, "Real-time communication network using firebase cloud IoT platform for ECMO simulation," in *2017 IEEE International Conference on Internet of Things (iThings) and IEEE Green Computing and Communications (GreenCom) and IEEE Cyber, Physical and Social Computing (CPSCom) and IEEE Smart Data (SmartData)*, 2017.

[22] IST, "Gas sensor calibration," International Sensor Technology, CA, USA, 2014.

[23] D. A. Aziz, "Webserver Based Smart Monitoring System Using ESP8266 Node MCU Module," *International Journal of Scientific and Engineering Research,* vol. 9, no. 6, pp. 801-807, Jun. 2018.

[24] M.M.R. Manu, R. Saha, S.A. Hoque, A. Hoque, "Remote Environmental Data Analysis Using Sounding Rocket," *International Journal of Engineering and Technology,* vol. 11, no. 6, pp. 1209-1221, 2019.

[25] Air Quality Index, "AQI Calculator," 02 February 2020. [Online]. Available: https://www.airnow.gov/aqi/aqi-calculator. [Accessed 02 Feb. 2020].

[26] The World Air Quality Project, "Dhaka US Consulate Air Pollution: Real-time Air Quality Index (AQI)," 06 January 2020. [Online]. Available: https://aqicn.org/city/bangladesh/dhaka/usconsulate/. [Accessed 06 Jan. 2020].

[27] M.B. Karuppasamy, S. Seshachalam, U. Natesan, R. Ayyamperumal, S. Karuppannan, G. Gopalakrishnan and N. Nazir, Air pollution improvement and mortality rate during COVID-19 pandemic in India: global intersectional study. Air Qual Atmos Health vol. 13, pp. 1375–1384, Aug. 2020.