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Design and Development of Electronic Nose for Explosive Chemical Detection

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***Abstract*--- Prior research into devices pertaining to chemical leakage detection has led to the development of Electronic Nose systems. They have traditionally been used in chemical plants to detect the leakage of alcohol and ammonia fumes. Restrictions due to the stationary nature of these systems have led to poor detection and unreliable location sensing of said leakages. The present work incorporates a Electronic nose system involving a mobile sensing unit with improved range of detection and GPS location monitoring capabilities. The implementation includes a functional prototype, an experimental model for testing with an accuracy of 84 percent, and a User Interface with easy access to data acquired by the system.**

***Keywords*--- Electronic Nose, Microcontroller, Sensors, Chemical detection**

I. INTRODUCTION

In recent times there have been many reports of mass deaths happening due to mishaps in handling Oxygen tanks or manufacturing plants and even leakages which lead to uncalculated shortages in the hospital facilities leading to loss of many lives .The infamous Bhopal Gas tragedy which took the nation by storm , in what is the biggest industrial disaster of the last hundred years in India, 5295 people died and 5,27,894 were affected after being exposed to some 40 tonne of methyl isocyanate gas leaked from a pesticide plant. It has been more than 35 years since the incident which happened on December 3, 1984, but there is still a massive debate on this industrial mishap.

To look at more recent events like the LG polymers tragedy occurring due to unattended styrene gas or the Beirut explosion caused by the improper storage of 2,750 tonnes of ammonium nitrate that claimed around 200 lives leaving another 7500 injured and 300,000 homeless leading to a massive collateral damage of $15 Bn could be prevented by periodic risk assessment tests performed remotely and monitored via AI to predict,prevent and alert authorities as well as citizens in the vicinity of such mishaps could effectively save lives and prevent damage to asset .

Many gases such as Ammonia,Ethanol ,Methanol used in manufacturing and industrial settings are highly combustible or flammable, if they come into contact with heat, fire, static electricity, or other catalyst chemicals even for a minuscule of a second can lead to huge instances of national calamities like the once mentioned above .While some of them may be detectable by close observation and human senses, few others can quickly be undetectable by olfactory fatigue, in which a constantly present scent or odour becomes unnoticeable by the human nose and some of these harmful gases do not provide any visual or olfactory cues in order to be detected. When these combustible harmful and highly reactive gases become concentrated in a given industrial setting such as a warehouse or disposal site or in the vicinity of these industrial factories , they represent an incredibly dangerous situation that can result in an explosion that can endanger not only employees, but others in the nearby region . Gas detector prototypes can help quickly detect the presence and also pinpoint to the location ,pressure reading ,humidity ,temperature and other important data which help the subject matter experts arrive at a conclusion as to how to resolve the problem at hand and method of operation that has to be adopted to mitigate risk and avoid further complications and provide employees ,local residents and other stakeholders with early warning so they can mitigate the situation or evacuate to safety.

The design of an E- Nose based system allows for early detection of explosive and toxic chemicals with high accuracy. The E-Nose can be incorporated and tested subject to specific use case scenarios which include an aerial drone and land rover to facilitate a mobile system and to expand range. Building an Api based interface to

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alert relevant authorities based on data provided by the E-Nose can decrease the frequency of leakages and accidents in the industry.

The E-nose can be used in various cases like preventing terror attacks in crowded places such as stadiums,auditoriums,metros,airports .They can also be made use of in the food, preservation,brewery industry .They can also be made use in at home or hospital setup for detection of pollutants and allergens.

The main objectives being looked at in this project would be : To design an Air Quality monitoring system to check particulate matter (PM), humidity, temperature, altitude and pressure levels. Design a system to detect the presence of explosive chemicals and measure the concentration of the various gases in the environment/surrounding.Test in a controlled environment, a functional prototype for an electronic nose to be used in industrial automation setting.To development a graphical user interface to display the concentration of gases and to notify the concerned authorities on crossing the predetermined levels.

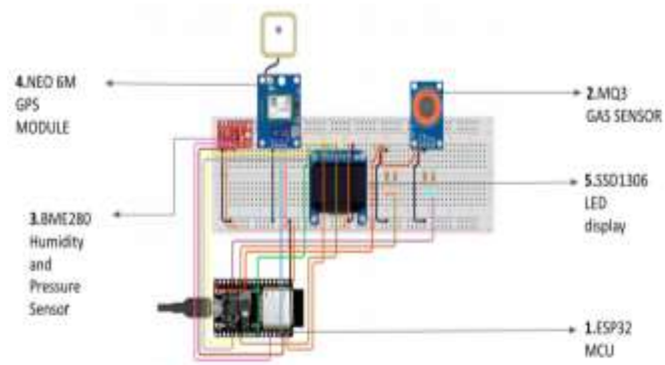
II. METHODOLOGY

The developed prototype can be mounted near the area of potential leakages or at strategic locations in chemical industry sites such as disposal ,storage or stockpiling sites.It can also be mounted on autonomously controlled mobile objects such as a land rover or quadcopter.The data gathered can be viewed real time on the Telegram bot API dashboard interface as well as tabulated for further analysis and pattern recognition in a data server using SQL.

The prototype involves the usage of the following sensors and components as illustrated in the Interfacing diagram :

A. Sensors and Components

1. ESP32-Microcontroller Unit
2. MQ-3/MQ135 - Gas Sensor, AQI sensor
3. BME280-Temperature, Humidity, Pressure, Altitude Sensor
4. NEO 6M -GPS Module
5. SSD1306- 0.96”- OLED display



/figure 1
/Interfacing Diagram

1. ESP32-Microcontroller Unit

/figure 2
/Esp32 MCU

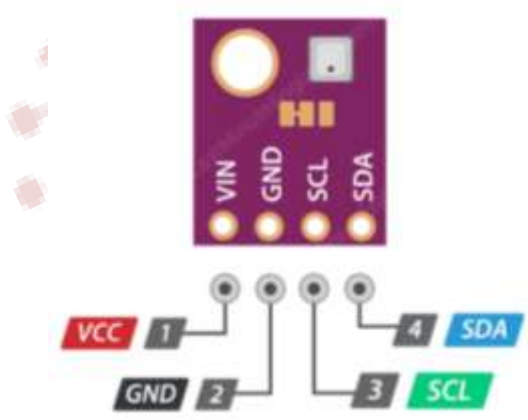
It is a feature-rich MCU with integrated Wi-Fi and Bluetooth connectivity for a wide-range of applications,which is capable of functioning reliably in industrial environments, with an operating temperature ranging from –40°C to +125°C. It Includes features such as fine-grained clock gating, various power modes and dynamic power scaling.It is highly-integrated with in-built antenna switches, power amplifier, low-noise receive amplifier, filters, and power management modules. The main application of this MCU is to integrate sensors in devices that are required to be mobile.

2. MQ-3/MQ135 - Gas Sensor, AQI sensor

/figure 3
/MQ3 Gas/AQI sensor

The MQ3 gas sensor is compatible with most of the microcontrollers.One of the most important features which makes it stand out in the mobile deployment scenario is its Low-power standby mode.It also has Good sensitivity to alcohol gas and has low response time and cost and high sensitivity when compared to similar sensors. The main application of this sensor is to detect Alcohol, Methane, and Acetate in the environment .

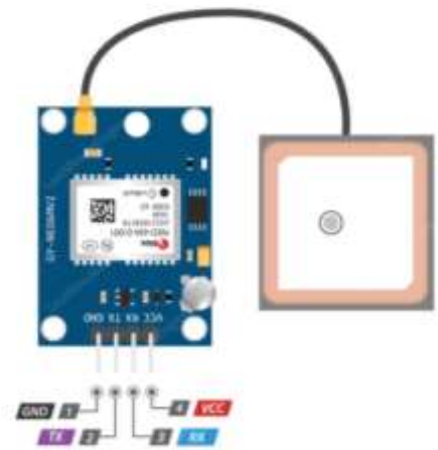
3. BME280-Temperature ,Humidity ,Pressure,Altitude Sensor



/figure 4
/BME280 sensor

The BME280 Humidity sensor and pressure sensor can be independently enabled/disabled which make it feasible for the use case scenario in the current setting.It is RoHS compliant, halogen-free, MSL1.It best opeartes in the Temperature Range of -40 to +85°C,which is about the optimum temperature range in industrial cases. The Humidity Range of 0% to 100% and Pressure Range of 300hPa to 1100hPa also serves the purpose in this application.

4. NEO 6M -GPS Module



/figure 5
/GPS Module

An essential component of the mobile E-Nose system is the GPS module to ensure accurate positioning of the system in the chemical plant and deliver accurate positioning to the User interface in order to provide precise location of potential leakages.Ease of integration with other devices ,durability when used in Aerial operations and rough terrain make it an ideal choice .It Operates under harsh conditions upto 85 degree centigrade and in the range of upto 4.5 Km.

5. SSD1306- 0.96"- OLED display

/figure 6
/SSD OLED Display

The most common use case the data from the sensors is viewed on the telegram bot api or the database but when mounted on strategic location is the industrial site or for a quick look in the home hospital scenario a display is vital .It can also be used for testing ,verification and troubleshooting of the prototype .

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It has a 128×64 pixel resolution with 160° viewing angle. It can supply voltage 3V – 5V (supports both 5V and 3.31v logic devices). It Uses SSD1306 for interfacing hence can communicate through SPI or I2C. Multiple SPI or I2C devices are also supported.It can be easily interfaced with Arduino ,Pi and other devices .

B. Prototype

The electronic nose module consisting of the microcontroller unit and the sensor unit are mounted on a mobile system to increase the range of the electronic nose and to enable a more accurate detection of the location pertaining to the leakage. The Electronic nose is mounted on an aerial drone and land rover and is set to periodically move through the premises of the chemical plant in order to monitor the readings at a regular interval. On detection of an irregular reading, the user interface is notified of the respective reading along with a precise GPS location of the point of irregularity. The readings and location are stored continuously on to the central data base.

C. Experimental setup

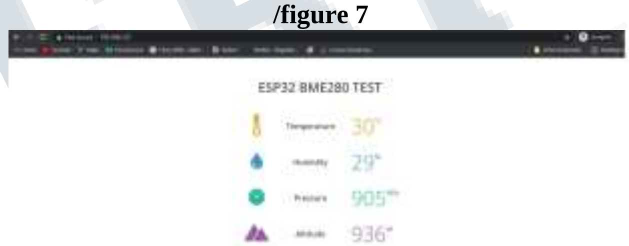
In order to test the accuracy and functioning of the prototype, experiments with substances of different origins were used. To state a few ways ,the prototype was subjected to the outside environment in an urban neighbourhood to see if is capable of picking up pollutants and other emissions ,these results were further compared with the nearest Central Pollution Control Board (CPCB) reading .Other techniques such as testing it a controlled room environment with alcohol contamination achieved via a deodorant spray, and other similar techniques to test all the intended capabilities of the prototype were completed and made ready for the prototype to be deployed in an uncontrolled outside environment.The results of the same were made available in the Telegram bot api dashboard interface as well as tabulated in the SQL based server for reference as well as pattern recognition.

III. RESULTS

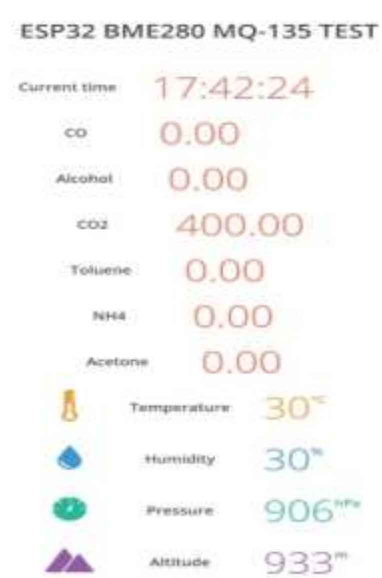
A.ESP32-BME280-MQ3 Weather Station

The ESP32 microcontroller functions as a low power smart IOT hub and BME280 as the primary sensor .This chip provides for the most integrated solution to the use case scenario with the help of its 2.4 GHz Wi-Fi and Bluetooth combo chip design.The ESP32 MCU is woken up periodically and only when a specified condition is detected (change in Temperature ,Humidity , Pressure,Altitude) by the BME280 sensor.Low duty cycle is used to minimize the amount of energy that the chip expends. The output power of the power amplifier is also adjustable to achieve an optimal trade off between communication range, data rate and power consumption.
The ESP32-BME280 Weather Station web interface and terminal output is shown in the figure 7,8 and 9.
The following parameters are plotted against the time scale to graphically visualize and compare the changes with time which can be seen in graphs numbered 1 to 5.

/figure 7

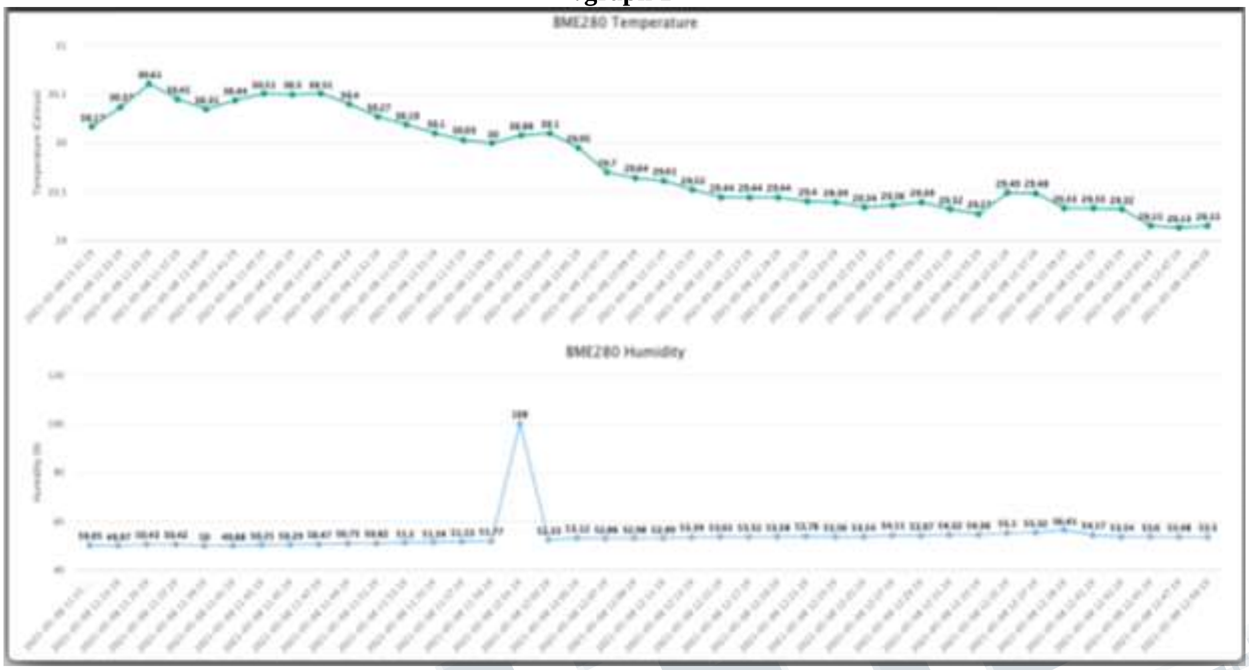


/figure 8

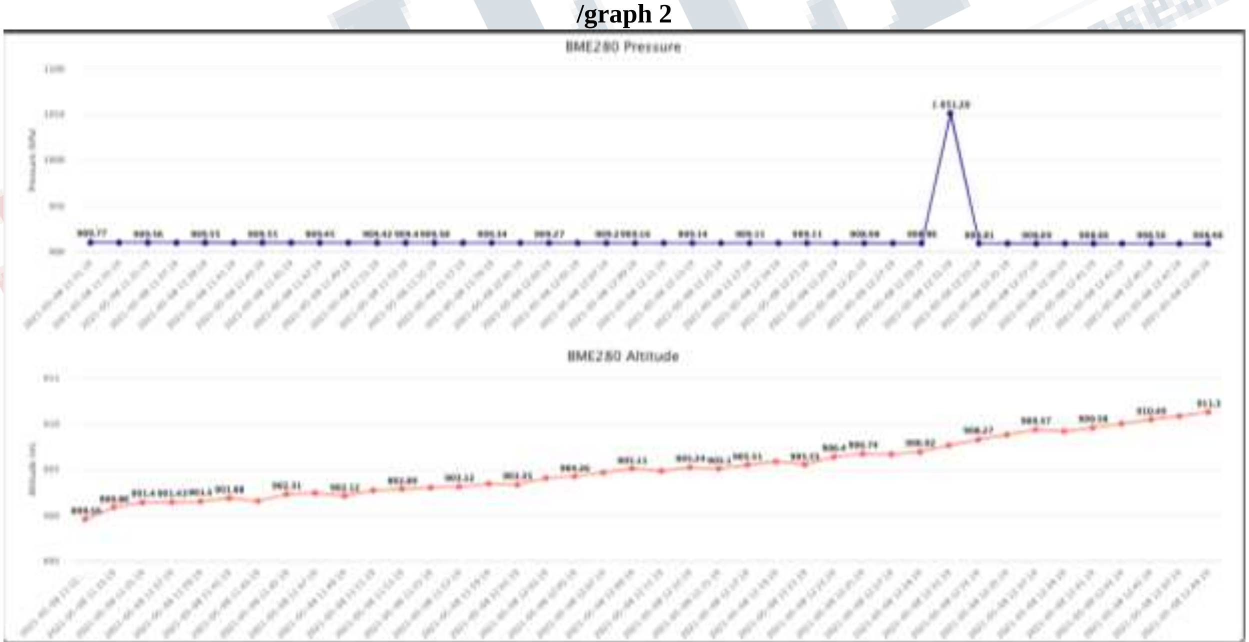


/figure 9

/graph 1



/graph 2



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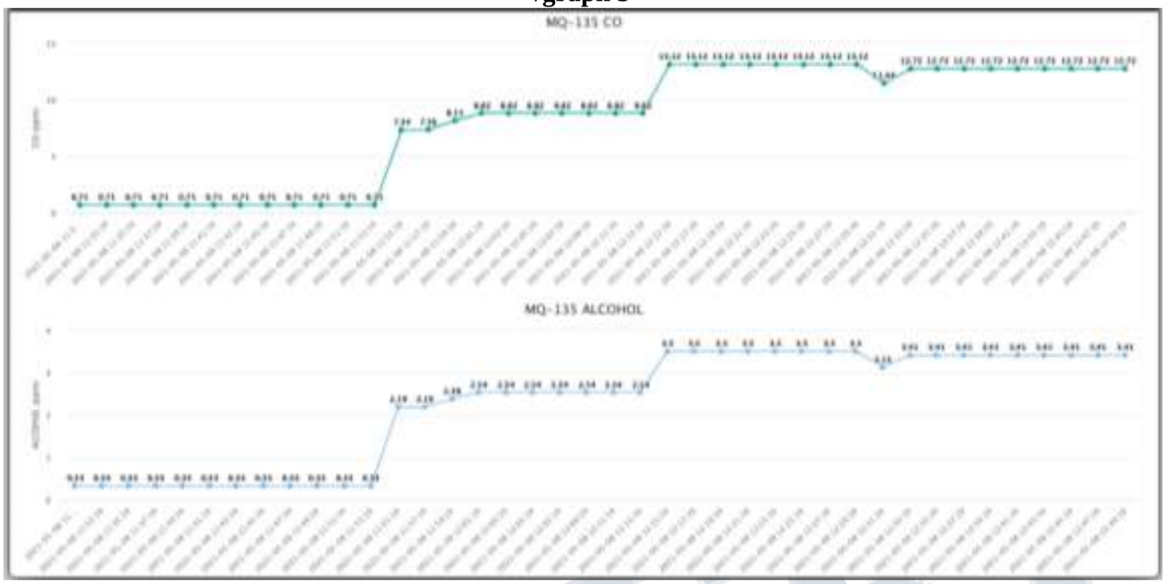
/graph 3



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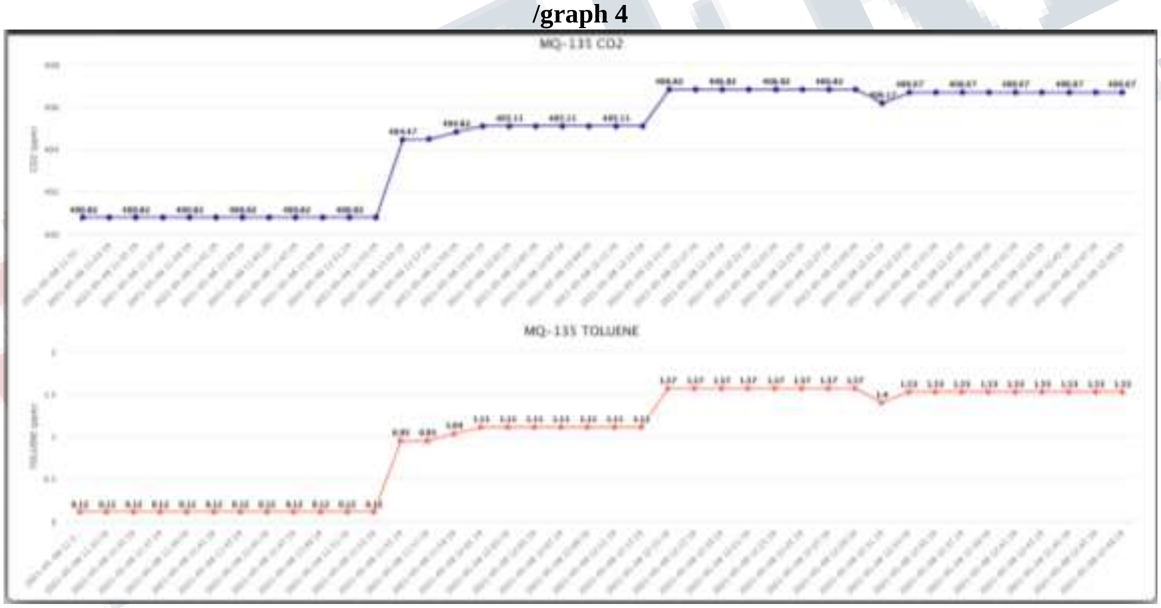

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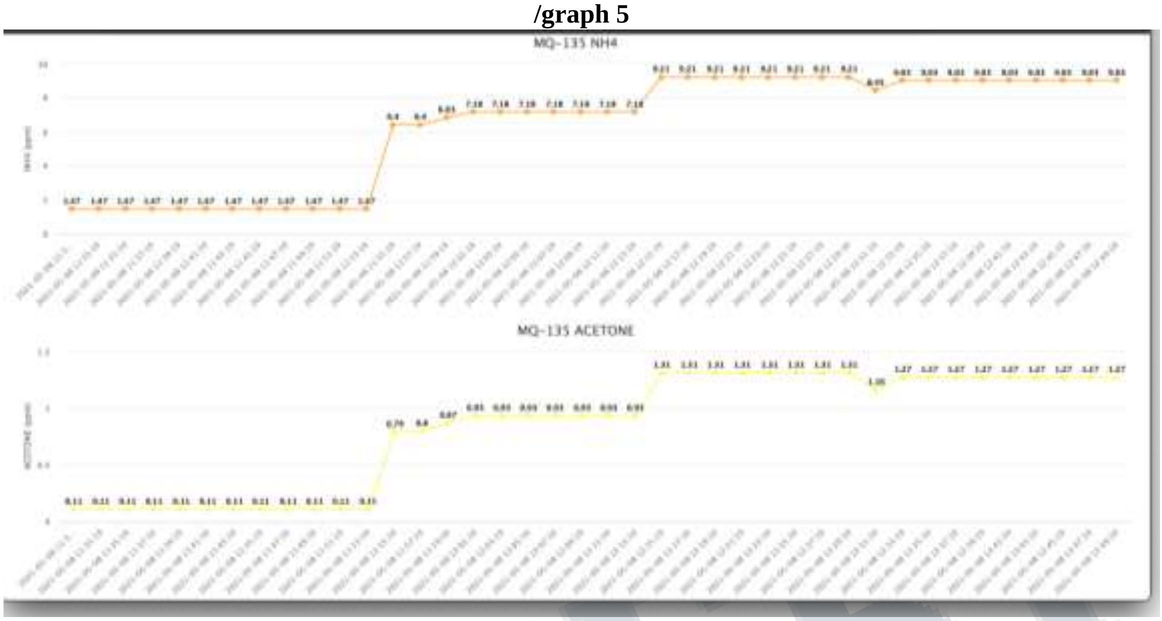
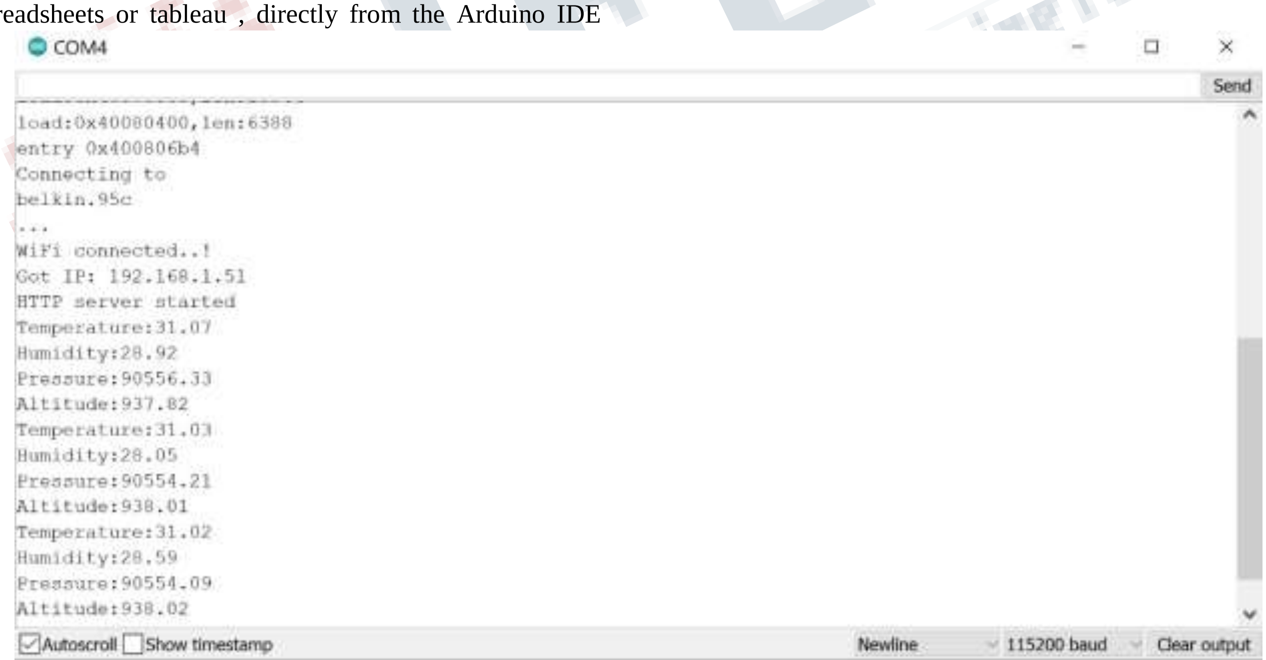
/graph 5



B. Arduino IDE Terminal

The arduino IDE is used to program,interface,integrate and derive output from the hardware components.The relevant data from the sensors can be tabulated in the form of spreadsheets or tableau , directly from the Arduino IDE terminal.

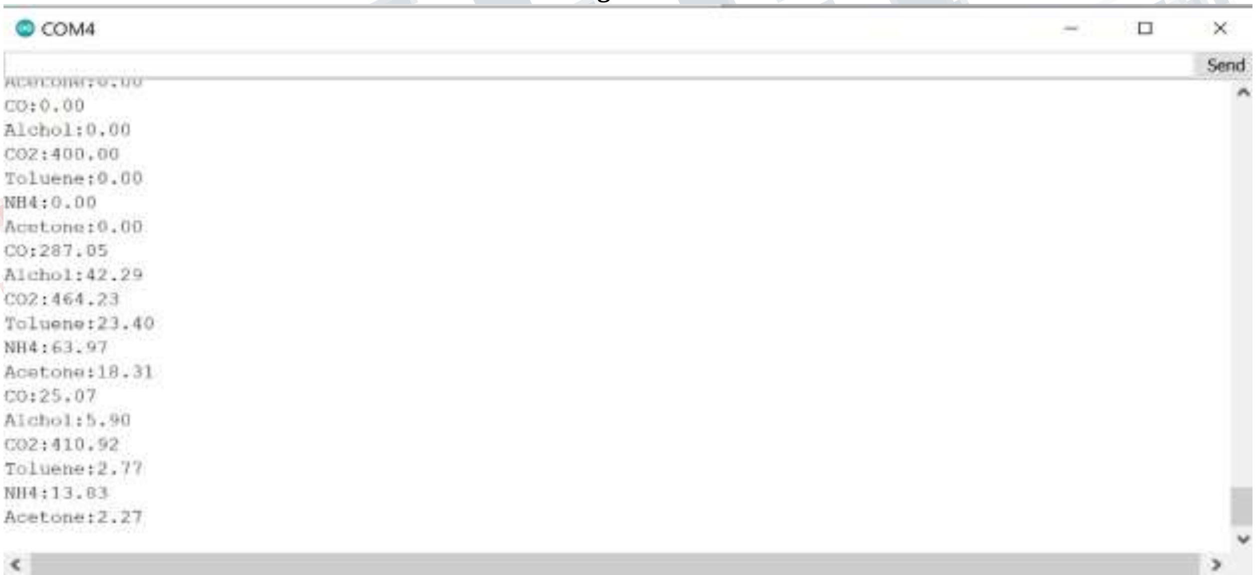
These can be fed to intelligent algorithms for Data analytics or used for future reference or pattern recognition.This terminal can be seen in figure 10.



/figure 10

The ideal scenario can be seen in figure 11 .On successful integration of the MQ135 Gas sensor with the other hardware components and subjected to an ideal scenario .It was observed that the presence of Acetone ,Alcohol,Toluene, NH4 and Carbon monoxide were found to be nil.Only the presence of allowable levels of Carbon dioxide was detected .The prototype was subjected to a controlled test case environment to verify the accuracy of the sensors and the following results were obtained as shown in figure 12.

/figure 11



/figure 12

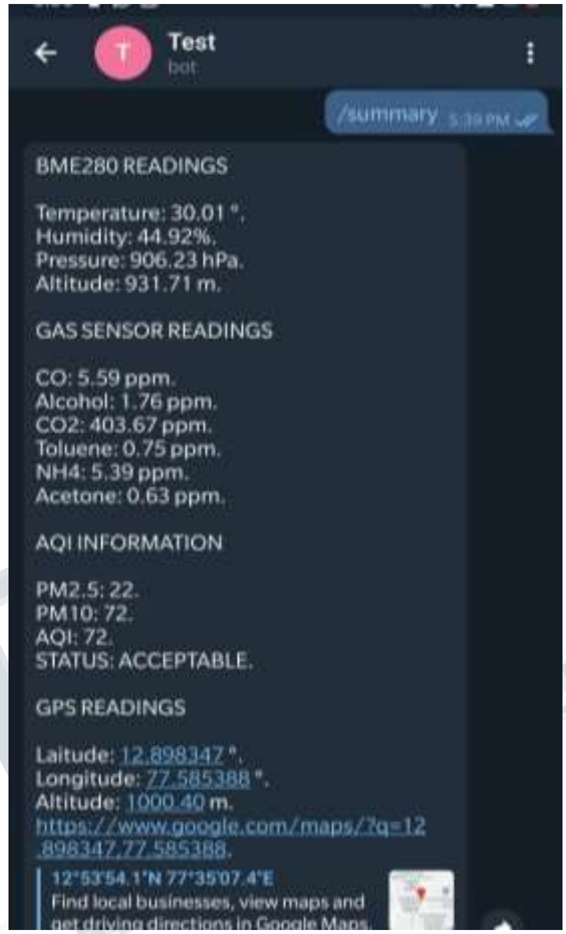
C. Telegram BOT API Dashboard

In the most common use case scenario details such as graphical representations,tabulations or charts are not required.The Telegram BOT API Dashboard provides for a quick ,interactive and real time view of the sensor readings which help in periodic analysis ,routine risk assessment and a better end user experience .The API has support on all platforms and with relatively good data connections the prototype can be remotely checked in from most mobile devices .The interface of the same is shown in the following figures.

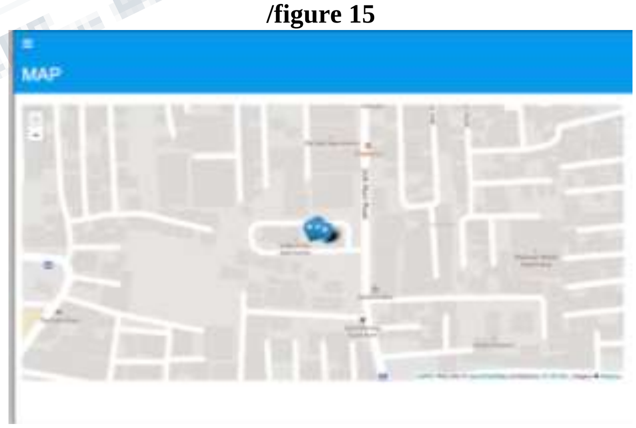
A summary of all reading can be obtained as demonstrated in figure 15.On expanding the GPS information the API pulls out the default map application from the end user and the interface can be viewed as shown in figure 16.

/figure 13

/figure 14



/figure 15



/figure 16

D. Air Quality Index (AQI)

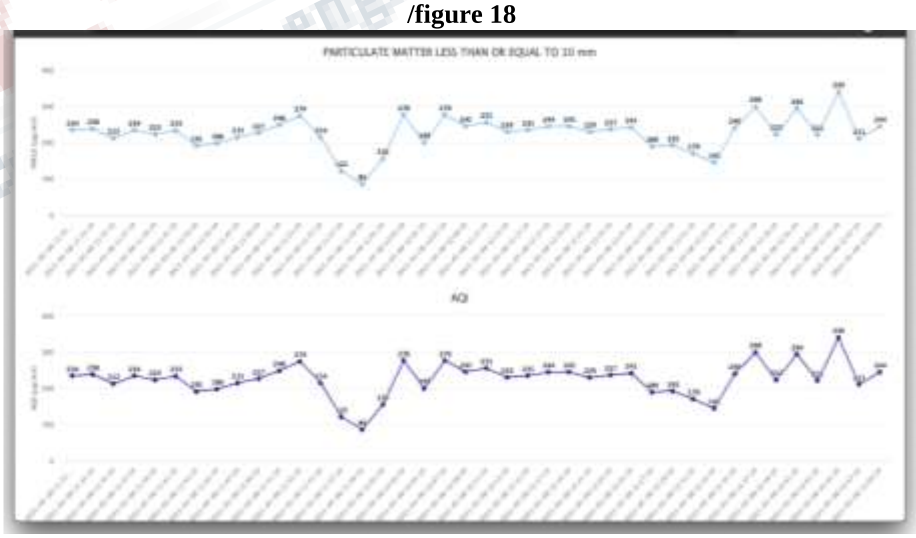
Air quality index measurements are taken at regular intervals via MQ135 sensor by the mobile E-Nose at various locations of the Chemical plant throughout the day and are displayed on the User Interface. These readings are then scanned for abnormalities and precise location of leakage can be detected using the GPS module.An AQI of 100 and above makes the air harmful for Humans and animals and is considered toxic. The in detail classification can be seen in figure 17.The Central pollution board of India places a restriction of 115 within the boundary of the Plant and restricts the value to 98.5 beyond the confines of the plant. The AQI recorded during Bhopal Gas Tragedy was recorded at 900. The AQI of the Plant explosion was recorded at 185.7 twelve hours prior to explosion.The AQI comparison drawn from the nearest CPCB and the prototype can be viewed in figure 18.The AQI and PM10 vs Time graph can be seen in graph 6 which represents the changes in AQI and PM10 particles with respect to time.

Remark	AQI	Possible Health Impacts
Good	0-50	Minimal impact
Satisfactory	51-100	Minor breathing discomfort to sensitive people
Moderate	101-200	Breathing discomfort to the people with lungs, asthma and heart diseases
Poor	201-300	Breathing discomfort to most people on prolonged exposure
Very Poor	301-400	Respiratory illness on prolonged exposure
Severe	401-500	Affects healthy people and seriously impacts those with existing diseases

/figure 17

AQI MEASURED AT NEAREST CPCB WEATHER STATION VS PROTOTYPE

/figure 18



/graph 6

IV. CONCLUSION

In this paper a remotely operable, mobile, low cost prototype was presented which is capable of providing AQI information ,detect presence of harmful gases as well monitor the environment for parameter such as temperature ,pressure ,humidity and altitude and also dispense the precise GPS coordinates of its whereabouts.The data obtained from the prototype was made available to the end user via an interactive real time Telegram BOT API dashboard .The data server also helps in tabulating the data for future reference or pattern recognition.

On comparing the data with the nearest Central Pollution Control Board (CPCB) readings an average accuracy of 84% was achieved when comparing 4 such parameters.

Knowing that the detection of explosive materials is very challenging, this prototype requires a more complex model to make it pertinent for a wider demographic of applications . Furthermore, it is going to be necessary to test the prototype using real explosive substances in real scenarios for concluding the usefulness and applicability in an industrial environment**.**

REFERENCES

[1] K. Brudzewski, S. Osowski, and W. Pawlowski, “Metal oxide sensor arrays for detection of explosives at sub-parts-per million concentration levels by the differential electronic nose”, Sensors Actuators, B Chem.,vol. 161, no. 1 -2012
[2] N. Sharma, M. Hooda, and S.K. Sharma, "Fabrication of micro-nano-mechanical structures for sensing application",International Journal of Applied Engineering Research, 13,6388-6393-2018
[3] A. Rossi, P. Ricci, and O. J. Gregory, “Trace detection of explosives using metal oxide catalysts”, IEEE Sens. J., vol. 19, no. 13-2019
[4] R. N. Gillanders, J. M. E. Glackin, J. Filipi, N. Kezic, I. D. W. Samuel, G. A. Turnbull, "Preconcentration techniques for trace explosive sensing", Sci. Total Environ. 658-2019.
[5] P. López, R. Triviño, D. Calderón, A. Arcentales and A. V. Guamán, "Electronic nose prototype for explosive detection",CHILEAN Conference on Electrical, Electronics Engineering, Information and Communication Technologies (CHILECON)-2017.
[6] Yijiao Chen"Consequence Simulation and Risk Assessment Model of Liquid Ammonia Leakage Accident Based on PHAST Software,"2020 International Conference on Advance in Ambient Computing and Intelligence (ICAACI), Ottawa, ON, Canada-2020.
[7] Musab Asad,Othman Al Aidaros,Raahim Beg”Development of Autonomous Drone for Gas Sensing Application “International Conference on Electrical and Computing Technologies and Applications (ICECTA)-2017.
[8] Alphus Dan Wilson,”Review of Electronic-nose Technologies and Algorithms to Detect Hazardous Chemicals in the Environment,”IEEE Access ,Tel Aviv -2013.
[9] Tanaya Das,Dhruba Jyoti Sut,ishal Gupta “A Mobile Robot for Hazardous Gas Sensing”International Conference on Computational Performance Evaluation (ComPE)-2020.
[10] Lei Shu ,Mithun Mukherjee “A Survey on Gas Leakage Source Detection and Boundary Tracking," in IEEE Access, vol. 4, pp. 1700-1715-2016.
[11] YA. H. Abdullah et al., "Development of ESP32-based Wi-Fi Electronic Nose System for Monitoring LPG Leakage at Gas Cylinder Refurbish Plant," 2018 International Conference on Computational Approach in Smart Systems Design and Applications (ICASSDA), Kuching, Malaysia, 2018, pp.-2018
[12] Musab Asad,Othman Al Aidaros,Raahim Beg”Development of Autonomous Drone for Gas Sensing Application “International Conference on Electrical and Computing Technologies and Applications (ICECTA)-2017
[13] AT. Pötsch, L. Pei, K. Kuladinithi and C. Goerg, "Model-driven data acquisition for temperature sensor readings in Wireless Sensor Networks," 2014 IEEE Ninth International Conference on Intelligent Sensors, Sensor Networks and Information Processing (ISSNIP), Singapore, 2014
[14] Tanaya Das,Dhruba Jyoti Sut,ishal Gupta “A Mobile Robot for Hazardous Gas Sensing”International Conference on Computational Performance Evaluation (ComPE)-2020
[15] N. Naji, M. R. Abid, N. Krami and D. Benhaddou, "An Energy-Aware Wireless Sensor Network for Data Acquisition in Smart Energy Efficient Building," 2019 IEEE 5th World Forum on Internet of Things (WF-IoT), Limerick, Ireland, 2019.