An IoT based System for Domestic Air Quality Monitoring and Cooking Gas Leak Detection for a Safer Home

Kalpesh Gupta, Gokul Krishna G and Anjali T

Abstract—**Air pollution is a severe health issue in today's contemporary world. In India, at least 40 million people breathe unsafe air (i.e. 10 times or more over the WHO safe limits). The main sources of air pollution are well known - emissions are from cars and factories, while much of the emissions in rural areas is produced by burning biogas for cooking food and keeping it hot. Moreover, with the increased usage of cleaner domestic and commercial cooking fuels such as LPG and CNG, it poses a great risk involved in case of leakage, specifically in places where the domestic fuel is delivered through gas pipelines. Thus, there is a high and important need for us to know about the concentration of these gases around us indoors so that we can take up appropriate steps in case it increases. Here we are proposing a low cost indoor air monitoring system which can be used for domestic air monitoring purposes in our homes or personal indoor spaces to measure the quality of air in terms of the concentration of harmful gases like CO2, smoke, LPG leak detection, CNG leak detection etc. and can intimate the appropriate gas agencies in case of emergency.**

Index Terms—**Air quality, CNG or LPG leak detection, MQ – 135, MQ – 2, MQ - 6**

I. INTRODUCTION

AIR is contaminated due to industrial release of poisonous gases, vehicle emissions and increased concentration of harmful gases in the immediate surroundings and particulate matter. Levels of pollution are exploding i.e. increasing exponentially due to factors such as manufacturing, urbanization, population increase, excessive use of automobiles etc., which can affect human health. Air pollution is increasing in contemporary world [1].

A new global study on air quality patterns shows that urban air pollution rates in the Region have risen by more than 5% in over two-thirds of our cities [2].

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In addition, natural impacts from the storms of dust, forest fires, sea salt along the coastal line and open field fires during the time of harvesting, a significant portion of air pollution in Indian cities stems from gas, biomass, petrol, coal, and suspended dust and the burning of waste all year round [3]. So, opening the indoor house window in urban areas is not actually providing us with the clean air but actually polluted air. Majorly the attributes of pollutions that needs to be considered on a domestic scale is CO2 and SO2 that generates out of the fossil fuel combustion, burning of wood etc.

Due to air pollution, over 1.2 million people died in India in 2017 [4]. The third highest cause for deaths is air pollution in India among the all health risks, ranks just above smoking; worldwide more people die from air pollution-related diseases than from road traffic accidents or malaria is shown in Fig. 1 [5].

In addition, the LPG cylinders that we use in our homes, poses a great threat to life and property if not handled properly. Liquefied petroleum gas or liquid petroleum gas (LPG) is also known as pure propane or butane. LPG is a highly flammable blend of hydrocarbon fuels used as fuel in cooking appliances, heating devices and cars [6]. Liquefied petroleum gas is a colorless, odorless liquid that evaporates readily into a gas. An odorant is usually being added with the gas tfo help detect the leaks.

LPG can escape as a liquid or a gas. If it leaks as liquid form, it will evaporate fast and since it is heavier than air, it will form a comparatively large gas cloud that will fall to the ground. These LPG vapours can rush alongside the ground for long distances, and can get gathered in basements or drains [7]. When the gaseous form encounters an ignition source, it can catch fire or burst. Cylinders will spontaneously burst into flames if they are engaged in a burn. LPG can cause cold burns on the skin and at high concentrations, it can serve as an asphyxiant. [7]

Around one-sixth of all deaths from accidental fires between 2010 and 2014, with 19,491 deaths are from exploding cooking gas cylinders and stoves. [8]. So, In this paper we are proposing a low cost, low power system of domestic, indoor and small scale commercial places.

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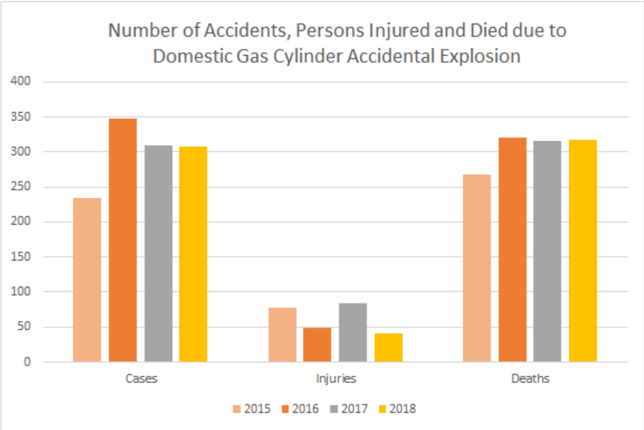

Fig. 1. No. of Accidents, persons injured and died due to Domestic Gas Cylinder Accidental Explosion [9].

A single system will cater the needs of both air quality monitoring in indoors due to harmful gases like CO2, smoke etc. and the LPG or CNG leaks and then prompt us with the necessary action needed to be taken on the LCD screen [9].

The paper also specifies the significance of this system, some of the past works in this reference followed by the components of the system and its working. It also discusses the further betterment of the system.

The paper begins with the related work which is given in section II. For that the proposed methodologies are given in section III. The next section IV and section V has the description of components and proposed solution respectively. Section VI is concluded with Conclusion part.

II. Related Works

Kan, Zhe, Shaohang, Xiong and Wei proposed a new-method to implement air quality observance system using state-of-art IoT techniques. The system is empowered by portable air quality sensors and transmitted through low power WAN. All data is processed and analyzed in IoT cloud. It uses extensive infrastructure and networks as being designed for the large outdoors like city, which may not be required for the low scale domestic purpose [10]

Sumanth Reddy Enigella and Hamid Shahnasser suggested a low cost IoT based solution that monitor the air quality index using the MQ-135 sensor, which is a low cost sensor, and based on the data collected from the sensor, it is sent to the cloud for further processing. They are visualising the air quality values over the map after analysing the data collected over a period. [11] However, our system focus is to intimate the user in home to take appropriate action and data can be collected over the cloud for the user so that he can undertake the improvements in their daily actions which are leading to the productions of CO2 deteriorating the quality of air. Therefore, there is no need to map the data; hence, it will reduce the cost.

C. V. Hari, Shelvin Varghese, Joshua Benny and Mohammed Razil suggested a LPG monitoring and detection system for the detecting the leakage of LPG and whether the cylinder is empty or not by analysing the weight of the cylinder [12]. Again, it's an IoT based system which uses MQ- 6 sensor and weight sensor in the system.

G Spandana and R Shanmughasundram have implemented an IoT based system, which is connected to cloud using ESP8266 for finding out toxicity in atmospheric gases [13].

Pt Nithia and S. Ullas have proposed a system to determine the concentration of nitrogen, oxygen, carbon-di-oxide and cooking gas, (which consists of methane and little quantity of propane, butane and ethane) in kitchens and notify people to take appropriate action when a threshold is crossed [14]. Santosh Hariharan proposes an instrumentation design of a device that can monitor the pollutants like SO2, NO2, CO, hydrocarbons and dust [15].

III. Proposed Methodology

A. *Contrast with existing systems*

For detecting the air quality (CO2 levels) and LPG leakage inside a building or room, there are lot of commercial sensors based devices are available. However, they are expensive since they use much precise sensors and sophisticated circuitry thus consume more power. However, such systems are not required for small scale and personal use.

Even though there are some low cost designs of the systems available, they are available as separate systems (separate for air quality and cooking gas leak detection) and have some components that are not required for our purpose, thus contributing to the increased cost.

B. *Proposed Design*

Here, we are suggesting a low cost low power system which will measure the concentration of CO2 in the indoor atmosphere also detect the leakage of the LPG or CNG (in situations like forgetting to switch off the stove or accidental turn on the gas stove by someone or accidental leak etc).

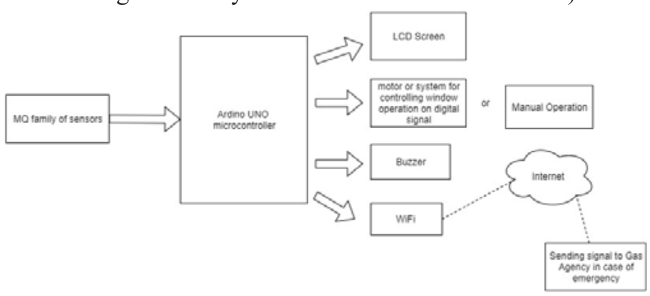

Fig. 2. Block Diagram of the proposed system.

It reports it to the user and give instructions to open the windows depending on the severeness of the situation. In addition to that, if it is severe, it will report to the fire protection organisations and gas agencies with the help of internet mail. Based on the discussed work, we are presenting a hybrid system fulfilling dual desires of monitoring the harmful gases like CO2 and leakage of domestic fuels.

The proposed system is empowered by the Arduino UNO microcontroller, low cost yet powerful microcontroller that will control all the operations of the system is shown in Fig. 2.

The system will be having a series of low cost MQ family sensors for detecting the concentration of harmful gases around us. These sensors include MQ-135, MQ-5 and MQ-6. This MQ family of sensors are of low cost, low power, which are suitable for this purpose. In case of emergency like LPG or CNG leakage, it will have a WiFi module, which will connect to internet and send a message to the gas agency intimating about the same. Here we will be briefly describing about the some of the components.

IV. Components Description

A. Arduino UNO microcontroller

Arduino Uno is based on ATmega328P microcontroller module is shown in Fig. 3. It is cheap and low power consuming microcontroller. Its operating voltage is 5V and input voltage range is 6V-12V.

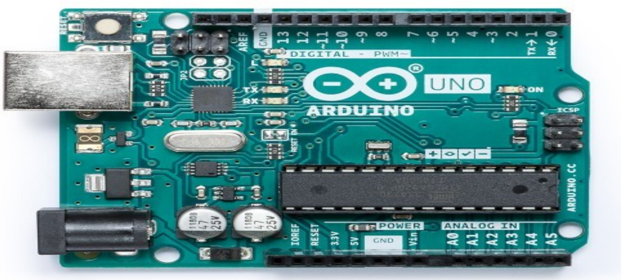

Fig. 3. Arduino UNO Rev3 Board [15].

It has 14 optical input / output pins (out of which 6 can be used as PWM outputs), a 16 MHz quartz crystal, a USB interface, 6 analog inputs, a power port, a reset button and an In-Circuit Serial Programming header. We can simply connect it to a computer with a USB cable, as it includes everything we need to support a microcontroller [16]; In addition, we can power it with a 9V battery, but the permissible voltages ranges from 7-20 V [17].

B. MQ-135 sensor

The MQ-135 gas sensors are utilized in air quality tracking systems and are appropriate for NH_3, NO_x, Nicotine, Benzene, Carbon, CO_2 identification or measurement. The sensor module MQ-135 has a virtual pin that enables the operation of this sensor even without a microcontroller and is useful when we are just trying to detect a single gas.

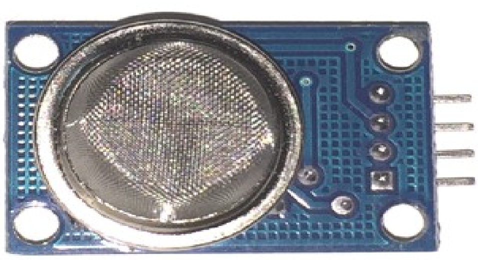

Fig. 4. MQ-135 gas sensor.

Its operating voltage is 5V [18]. In Fig. 4, MQ-135 Gas Sensor uses SnO_2 (Tin (IV) oxide) as a gas-sensing agent. Tin (IV) oxide has a higher resistance in clear air. As polluting gases increase, the gas sensor resistance decreases along with that [19].

C. MQ-6 sensor

The MQ-6 module is utilized for leakage detection of gas in home in industry equipment. This module has high sensitivity to iso-butaneous, LPG, propane and LNG. Detection of smoke from the cigarettes, cooking fumes and alcohol can be done with the help of MQ-6 sensor. The sensor module measures the gas concentration as an analog voltage equivalent to the gas concentration.

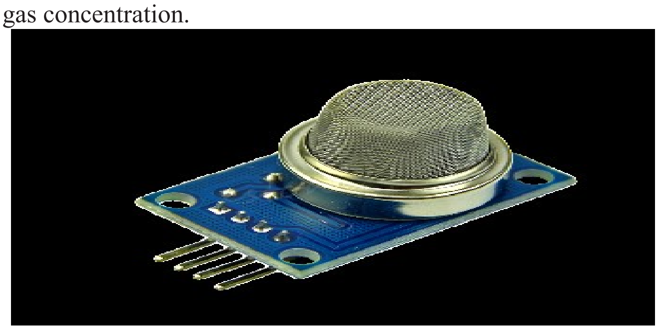

Fig. 5. MQ-6 gas sensor.

The MQ-6 can detect gas concentrations anywhere between 200 and 10000 ppm. This sensor has a fast response time and high sensitivity. It consumes low power. Its operating voltage is 5V [20]. The sensor's output is an analog resistance. MQ-6 sensor's sensitive material is Tin (IV) oxide (SnO_2), is shown in Fig. 5 which is less conductive in clean air. When the target combustible gas appears, the conductivity of the sensor is higher towards the rising gas concentration [21].

D. MQ-4 sensor

This is a simple and easy-to-use sensor, which is suitable for measuring concentrations of natural gas (mostly methane, CH_4) in the air. The MQ-4 detection ranges from 200 to 10000 ppm of natural gas anywhere.

Fig. 6. MQ-4 gas sensor.

The sensor's output, again like other MQ sensor mentioned, is an analog resistance. Its operating voltage is also 5V [22]. MQ-6 sensor's sensitive material is Tin (IV) oxide is shown in Fig. 6, which has less conductivity in clean air [23].

E. ESP8266 WiFi module

ESP8266 is a System-on-Chip (SoC) module is shown in Fig. 7. ESP8266 is developed by the Espressif system which enables Wi-Fi. It is mostly used for the development of embedded applications in IoT (Internet of Things) [24].

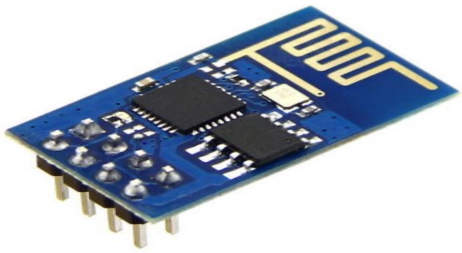

Fig. 7. ESP8266 WiFi module.

The ESP8266 package is a low cost portable wireless transceiver. IoT endpoints can be made using this package. It utilizes the Tensilica Xtensa L106-based 32-bit RISC CPU operating at 80 MHz (or overclocked to 160 MHz). It has a boot ROM of 64 KB, RAM data of 96 KB and RAM instruction of 64 KB. External flash memory is accessible through Serial Peripheral Interface (SPI) [24].

V. PROPOSED SOLUTION

The smart system that we are proposing here uses three types of MQ - family based sensor. MQ-135 sensor will help us to measure the concentration on CO2 in the surroundings. MQ - 4 or MQ - 6 sensor can be used depending on the domestic fuel that is being used is natural gas or LPG. These sensors actually sense the respective gases based on the variation in the resistance, their resistances decreases with the increases in concentration of the gases. Thus, the differences in resistances can be obtained which then is utilized to calculate the concentration of different gases based on the sensitivity graph given in their datasheet of respective sensors.

From the value of concentrations (in ppm), if it crosses the safe value range, the appropriate intimation is given to the user by displaying the apt action on the screen as described below and in case of severe emergency (levels are too high) , the buzzer will blow and if proper circuitry connected to the windows and other outlets in a home, then they will get open. The various levels of CO2 concentrations, on the basics of which the system will perform the actions, are listed in the Table I [25}.

TABLE I
DIFFERENT CO2 PPM RANGES

CO2 level	Action to be performed / Message to be displayed
250-400 ppm	Clean Air (Normal concentration (background) in outdoor in immediate surroundings air) “No special action to be performed”
400-1000 ppm	Clean Air (Typical Concentrations of occupied indoor spaces with good air exchange) “No special action to be performed”
1000-2000 ppm	Poor Air. "Please open the windows" advice will be given
2000-5000 ppm	Very poor and unsafe air. Windows and other outlets will be automatically opened, Going out advice will be given
>=5000 ppm	Severe situation, unsafe place "Get out of here immediately instruction"

In case of domestic fuel leak detection, if the leak detected was minor that is only for short duration (like accidental switch on of stove), then the buzzer and message on the LCD screen will alert then the user.

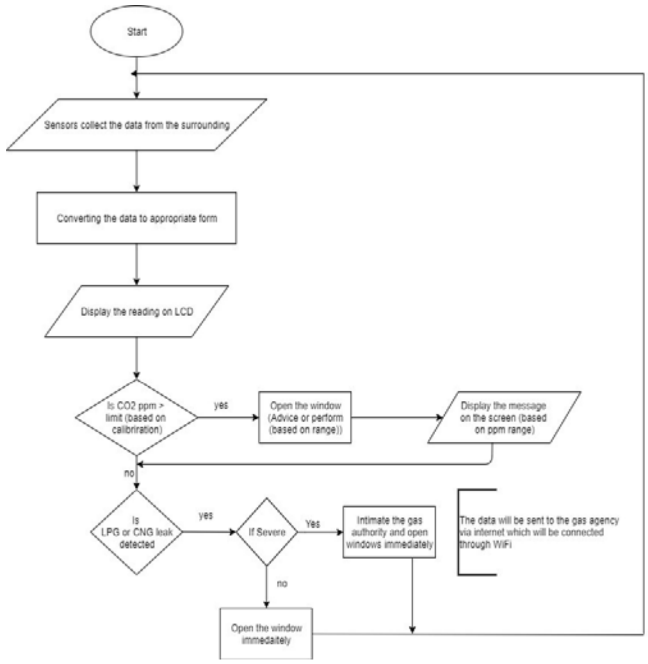

Fig. 8. Flowchart of the proposed system.

If the leak is severe, then the appropriate gas agencies will be intimated by using internet (connected through WiFi) using some cloud based service is shown in Fig. 8.

VI. CONCLUSION

Hence, we are proposing a hybrid low cost low power IoT based system for air quality determination and cooking fuel leak detection, enhancing the safety of the users in the house. Our system is able to detect any leaks of LPG or natural gas quickly with the use of low cost MQ-4 and MQ-6 sensor. A perfect tradeoff between affordability and safety is being achieved with this proposed solution. It can be further enhanced with the inclusion of more sensing units like that of SO2, NO2 etc., if the house is situated near to industrial or some commercial zones. Furthermore, the data collected can be stored on the cloud and can be analysed for certain relationships among them over a period. With current growing urbanisation, this proposed system is highly beneficial for domestic usage.

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