Early Warning Asthma Trigger Detection System

ABSTRACT:

A non-invasive, wearable and easy to operate wireless system has been developed to detect various environmental factors that trigger Asthma and Chronic Obstructive Pulmonary Disease (COPD) in patients and provide an early warning mechanism as a prevention measure. The system comprises of modules, consisting of four sensors that identify the pollutants in the environment and alert the user about the potential of the said pollutants to trigger Asthma. The sensors are connected to a wireless network facilitating the implementation of an efficient healthcare system in indoor as well as outdoor scenarios considering places with and without network connectivity.

INTRODUCTION:

Asthma is one of the most widespread chronic diseases in the world. According to the World Health Organization (WHO), Asthma is one of the major causes of hospitalisation of people, especially children in various countries facing high levels of pollution in cities, such as India. In the new era of gadgets and technology, people spend more time indoors considering their activity related work or leisure. However, indoor air quality conditions can directly affect the respiratory condition of the people. Thus, breathing air characterized by poor air quality leads to inhalation of the air pollutants into the lungs, causing serious damage to the respiratory tract and thus triggering Asthma. At the same time, long term exposure to polluted air can be a potential cause for asthma. To investigate the relation between the indoor and outdoor air quality and respiratory diseases, the measurement of concentration of gases such as CO, NO2, PM10, Volatile Organic Compounds (Acetone, Toluene, Ethanol, Etc.,) and physical parameters such as temperature and humidity are carried out. The proposed system provides an early warning for prevention of Asthma. This is asserted by the fact that the human body takes 14-16 minutes to respond to an asthma trigger. The work presents a wireless sensor network and information system (Device) for air quality monitoring. The data provided by the WSN may be published using cloud-based platforms with the information being accessible to users who can be alerted about the prevailing poor air conditions. The air quality monitoring network is based on Wi-Fi that are relatively low-cost solutions, with high data rate transfer.

OBJECTIVE:

The objective of this project is to develop a system to analyse the triggers of asthma and a device that can be used by asthma patients. This device can perform multiple functions that enable a physician to monitor the patient's condition and provide continuous care. The work consists of three modules. Module 1 is aimed at people having asthmatic conditions in rural areas where the network connectivity is poor and access to wireless communication is an issue. Module 2 is for asthmatic patients who are spending a substantial amount of their time in indoor units. This module has a relay circuit which is connected to an Air conditioner or room heater to stabilize the Indoor air quality. Module 3 works in the urban areas exposed to pollutants, dust, pollens etc., which are the major triggers for asthmatic patients. All the three modules provide personalized solutions for patients as well as necessary data for the physicians to facilitate data analysis and research.

DESCRIPTION (INCLUDING BLOCK DIAGRAMS):

COMPONENTS USED:

The product contains multiple sensors for measuring carbon monoxide, carbon dioxide, nitrogen dioxide, temperature, humidity, ethanol, pollens and other toxic gases which trigger asthma in the atmospheric air. ESP32and Arduino Nano are being used as microcontrollers. On the software side, we have a web service (Adafruit) with client–server architecture. Volatile organic compounds (acetone, toluene, ethanol, ammonia, carbon monoxide, carbon dioxide) are detected by MQ-135 Sensor. The DHT11 sensor is a temperature and humidity sensor, whose output voltage is directly proportional to the temperature in Celsius (Centigrade). NO_2 is detected by MICS-2714 which is a MEMS sensor used for highly accurate detection of the gas. PM2.5 sensor is used to detect fine dust and pollens (size ranging from 2.5µm-10µm). All these sensors are integrated for each module and the software runs in Arduino IDE platform.

MODULE 1: RURAL SETTING

This module is developed for rural areas where there is no/poor internet connectivity in order to alert the patient of unfavourable environment. This module has sensors integrated with Arduino Nano. The threshold of each gas is set according to the harmful levels of each gases. The alert is provided to the user in the form of simple LED indication. For a favourable environment the LED indicated is green, once the atmospheric levels of any of the harmful gases reaches the threshold, the LED turns red. This indication is used as an alert system. The module also includes a buzzer which aims to alert the Visually Impaired about the unfavourable environment they are exposed to. The basic block diagram of this module is as follows, refer to Fig.1.

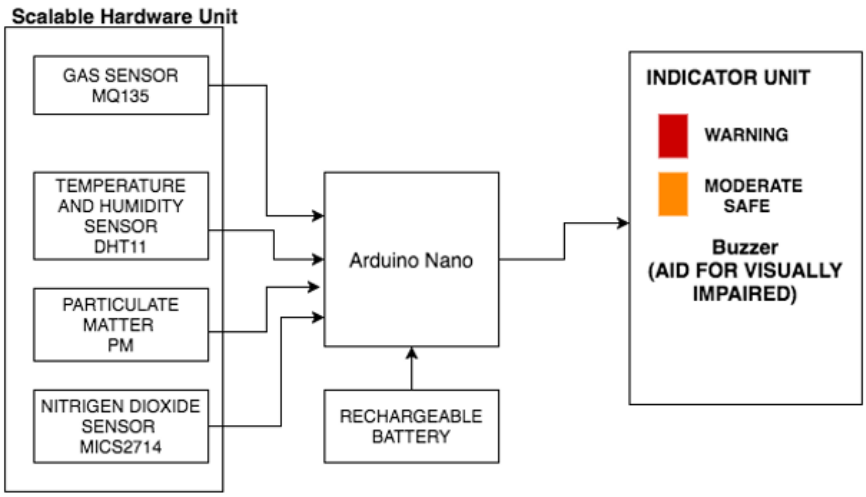


Fig.1 Hardware block diagram for areas without network connectivity

Please refer to Fig.2 and Fig.3 for details on the functionality of the prototype. Orange LED is used to indicate that the environment is moderately safe, after analysis of the recorded environmental parameters against their specified threshold. In this region, called as Moderately Favourable, the asthma triggering gases are less than their threshold, in ppm.

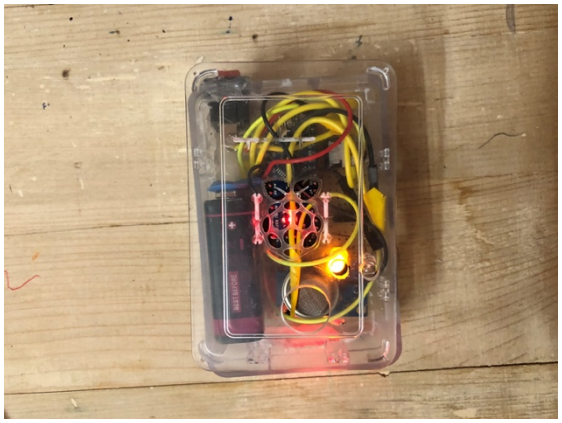


Fig.2 Light indication for moderately safe environment

Fig.3. shows the alert in the form of a Red LED, indicating that the environment is unsafe for the user and he/she has to move to safer regions as soon as possible to prevent the occurrence of Asthma attack. The environment is categorised as unsafe when the concentration of asthma triggering gases exceed the predefined threshold.

Fig.3 Light indication for harmful environment

MODULE 2: INDOOR UNIT

This module is developed for people who spend substantial amount of time in indoor areas, say a person working in the field of Information Technology. This module consists of a relay system which connects the device with an air conditioner, room heater or a home automation system. The optimum temperature and humidity is set in the software system. Once there is imbalance in the temperature or humidity, the relay system operates the air conditioner to bring back the normal or desired conditions. This system works in advance against the trigger and maintains balance in the indoor units. The various parameters obtained from the sensors are clouded to Adafruit platform for

future analysis. This module also has mobile based applications for locating the device, to alert the user about the trigger information and suggest information about the local doctor during emergencies. All the sensors are integrated to the Wi-Fi module (ESP32) which adds the feature of sensor scalability to the product. The basic block diagram of this module is shown below, refer Fig.4.

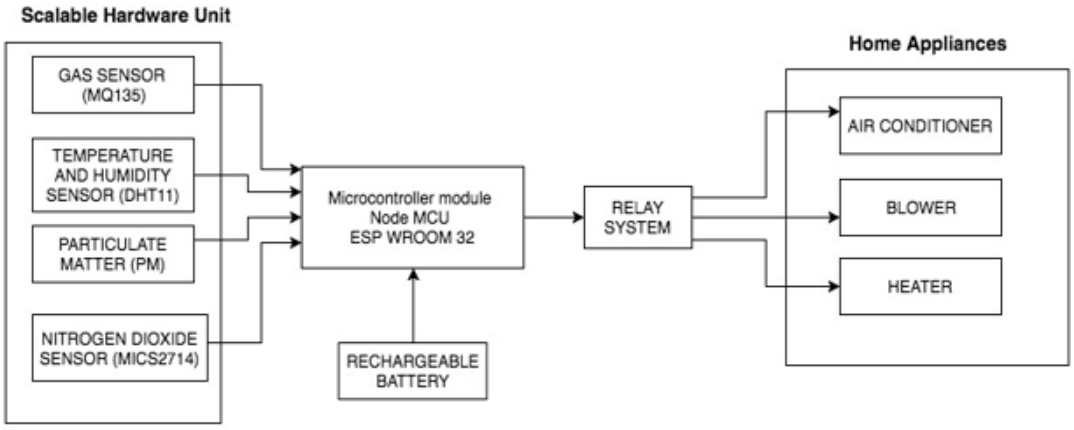


Fig.4 Indoor Unit Block diagram

The prototype which has been developed for the implementation of this module is shown below in Fig.5.

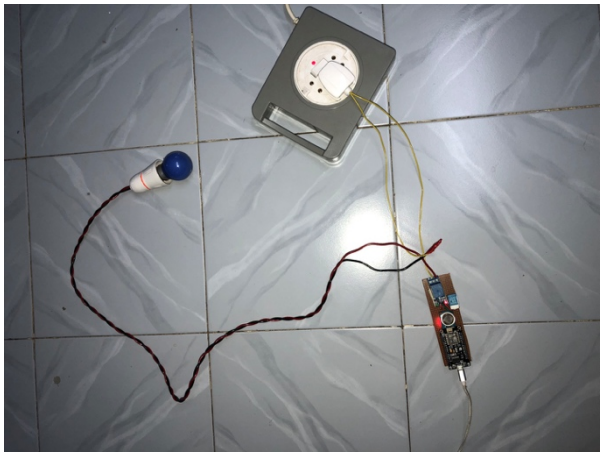


Fig.5 Indoor Unit Setup –relay off

In this setup, it is seen that the device is connected to a bulb, representing a home automation system. When the concentration of the triggers of Asthma (in PPM) is less than the specified threshold, the bulb remains in the OFF state. When the concentration of the triggering gases exceeds the specified threshold, the bulb is switched on, as indicated in the image below. As mentioned already, the bulb can be replaced by any other appliance such as an air conditioner, heater or a home automation system.

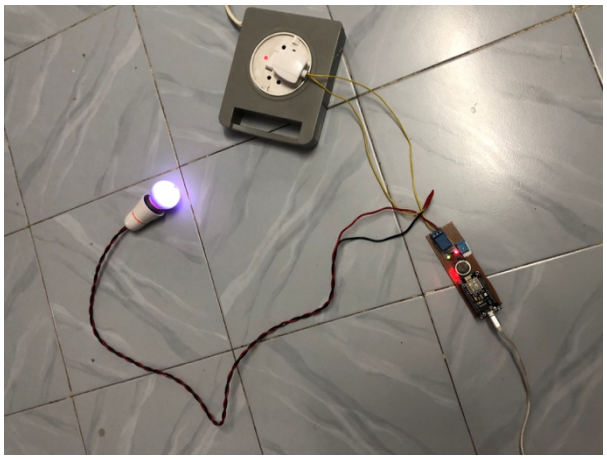


Fig.5 Indoor Unit Setup –relay ON

MODULE 3: OUTDOOR UNIT

This module is aimed at people living in Urban areas or outdoor environments. This module comprises of a combination of four sensors, used to detect, measure and alert the user about the potential of the environmental factors to trigger Asthma. The sensors MQ135, DHT11, PM2.5, MICS 2714 measure various parameters such as Ethanol, Acetone, Humidity, Temperature, Ammonia, NO2, Toluene, CO (Carbon Monoxide) and CO2 (Carbon Dioxide) in no specific order. The four sensors are integrated with NodeMCU and the values are stored in a cloud, here Adafruit IO, which is basically an Open Source Cloud Platform. The Adafruit IO allows the graphical and numerical representation of the measured values. This data plays a pivotal role in the analysis of an area for its potential triggers. The four sensors, along with the NodeMCU powered by a rechargeable battery form a scalable hardware unit, allowing integration of more sensors in the future. This module has an additional feature namely User Feedback and Alert System. This is a smartphone driven app which aims to provide information about the prevailing environmental conditions, local doctors, trigger related information and a feedback system in the form of a Questionnaire which aids the system in learning about the user specific threshold and thus provide improved personalised solutions. The threshold of each of the various parameters are fed into the software beforehand. When the measured values exceed the predefined threshold, an alert message is sent to the user by using IFTTT platform. The basic block diagram of this module is shown below, refer Fig.6.

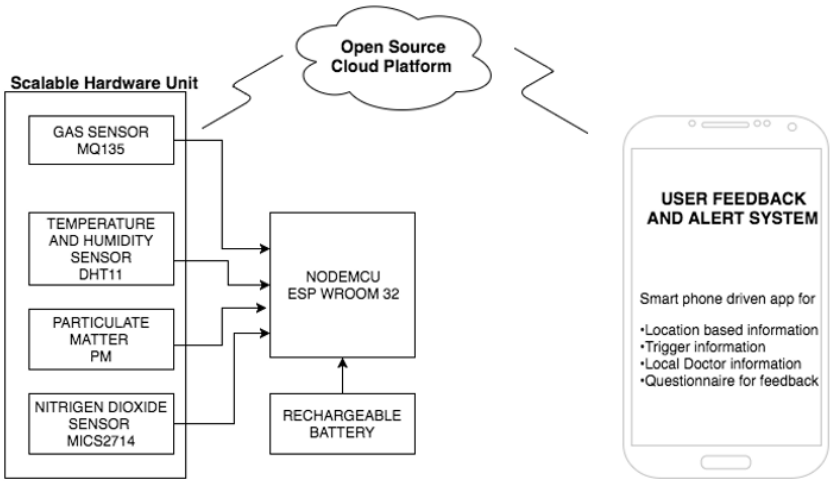


Fig.6 Outdoor Unit Block diagram

The basic setup for outdoor setup in given in Fig.7.

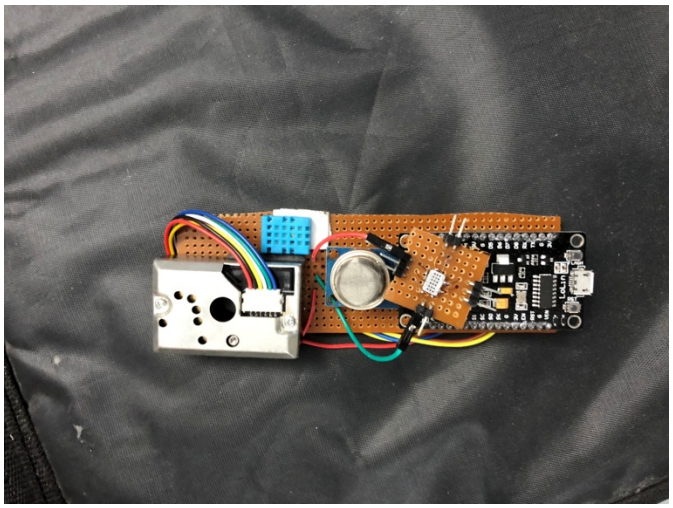


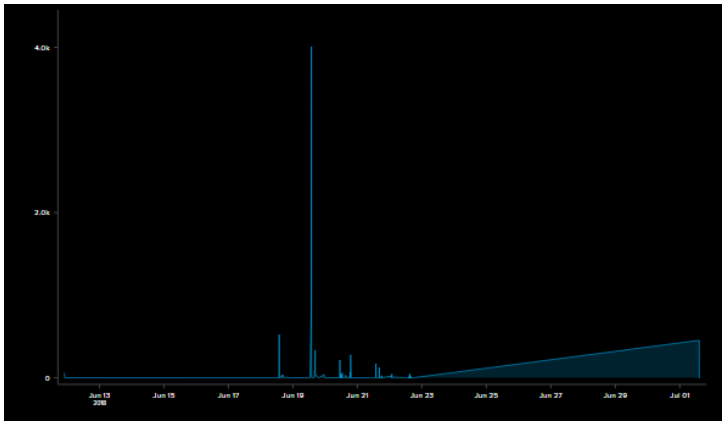
Fig.7 Outdoor unit basic setup

EXPERIMENTAL RESULTS

The numerical and graphical representation of various triggers is as shown below. These can be observed in the Adafruit cloud platform. Also, an SMS alert is sent when it crosses a certain harmful threshold (figures are given below for reference). For the setting without network connectivity and for the indoor unit scenario, results have been discussed in the previous section itself.

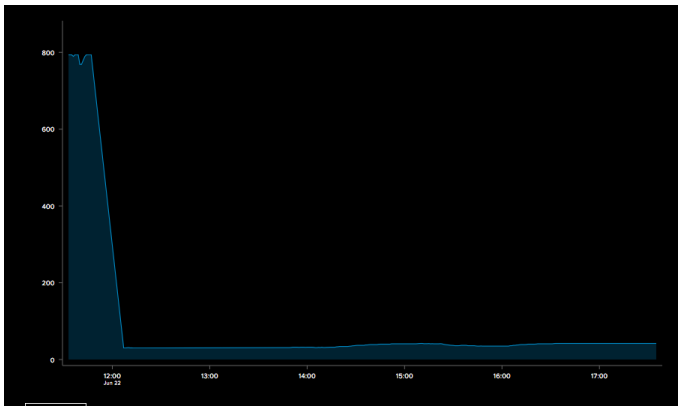
The portable device being exposed to different gases and how data is sent real-time and alert system is accomplished:

Ethanol



VALUE	CREATED
0.71	6 hours ago 2018-07-01 3:06:40 pm
0.67	6 hours ago 2018-07-01 3:06:22 pm
0.71	6 hours ago 2018-07-01 3:05:49 pm
0.76	6 hours ago 2018-07-01 3:05:32 pm
0.58	6 hours ago 2018-07-01 3:05:04 pm
0.54	6 hours ago 2018-07-01 3:04:44 pm
0.58	6 hours ago 2018-07-01 3:04:26 pm
0.58	6 hours ago 2018-07-01 3:04:05 pm
0.62	6 hours ago 2018-07-01 3:03:17 pm
0.67	6 hours ago 2018-07-01 3:03:00 pm
0.81	6 hours ago 2018-07-01 3:02:42 pm
1.04	6 hours ago 2018-07-01 3:02:24 pm
1.78	6 hours ago 2018-07-01 3:02:06 pm
5.48	6 hours ago 2018-07-01 3:01:49 pm
0.54	6 hours ago 2018-07-01 2:56:08 pm
0.54	6 hours ago 2018-07-01 2:55:47 pm
0.54	6 hours ago 2018-07-01 2:55:29 pm
0.54	6 hours ago 2018-07-01 2:55:12 pm
0.54	6 hours ago 2018-07-01 2:54:55 pm

Temperature

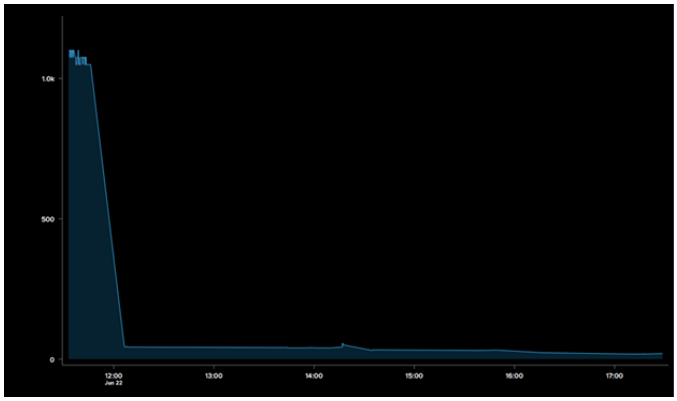


Actions

VALUE	CREATED	LOCATION
34.00	9 days ago 2018-06-22 2:20:05 pm	
34.00	9 days ago 2018-06-22 2:19:47 pm	
34.00	9 days ago 2018-06-22 2:19:28 pm	
34.00	9 days ago 2018-06-22 2:19:11 pm	
34.00	9 days ago 2018-06-22 2:18:53 pm	
33.00	9 days ago 2018-06-22 2:18:34 pm	
33.00	9 days ago 2018-06-22 2:18:17 pm	
33.00	9 days ago 2018-06-22 2:17:59 pm	
33.00	9 days ago 2018-06-22 2:17:41 pm	
33.00	9 days ago 2018-06-22 2:17:23 pm	
33.00	9 days ago 2018-06-22 2:17:05 pm	
32.00	9 days ago 2018-06-22 2:16:47 pm	
32.00	9 days ago 2018-06-22 2:16:15 pm	
32.00	9 days ago 2018-06-22 2:15:57 pm	
32.00	9 days ago 2018-06-22 2:15:39 pm	

First Prev 22 23 24 25 26

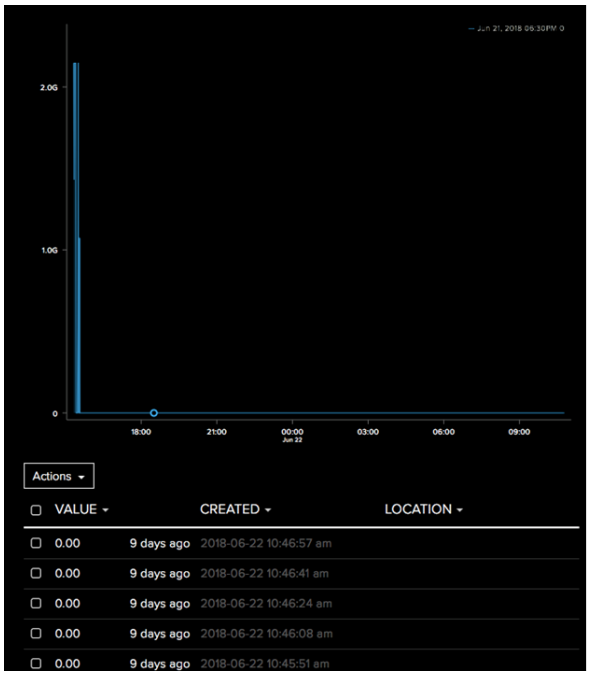
Humidity



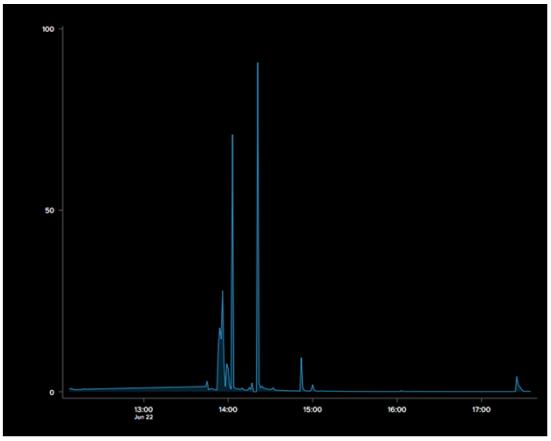
Actions

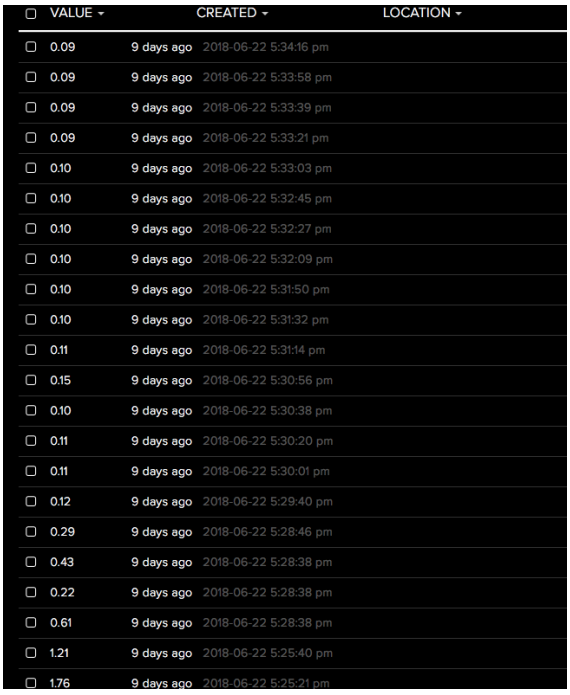
VALUE	CREATED	LOCATION
20.00	9 days ago 2018-06-22 5:28:38 pm	
20.00	9 days ago 2018-06-22 5:28:38 pm	
20.00	9 days ago 2018-06-22 5:28:38 pm	
18.00	9 days ago 2018-06-22 5:18:08 pm	
18.00	9 days ago 2018-06-22 5:17:50 pm	
18.00	9 days ago 2018-06-22 5:17:32 pm	
19.00	9 days ago 2018-06-22 5:17:27 pm	
18.00	9 days ago 2018-06-22 5:16:07 pm	
18.00	9 days ago 2018-06-22 5:15:48 pm	
18.00	9 days ago 2018-06-22 5:15:29 pm	
18.00	9 days ago 2018-06-22 5:15:11 pm	
18.00	9 days ago 2018-06-22 5:14:49 pm	
18.00	9 days ago 2018-06-22 5:14:30 pm	
18.00	9 days ago 2018-06-22 5:14:12 pm	
18.00	9 days ago 2018-06-22 5:13:53 pm	
18.00	9 days ago 2018-06-22 5:11:57 pm	

NO2(Nitrogen dioxide)

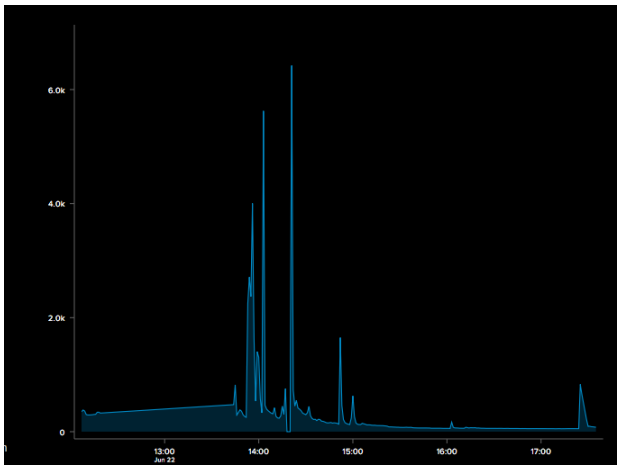


CO (carbon monoxide):





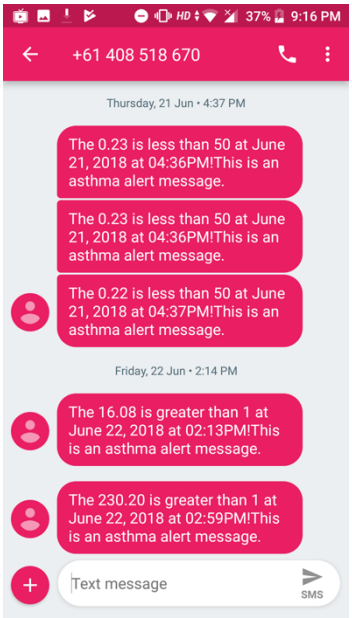
CO2 (carbon dioxide):



Actions

VALUE	CREATED	LOCATION
78.54	9 days ago 2018-06-22 5:34:15 pm	
78.54	9 days ago 2018-06-22 5:33:57 pm	
78.54	9 days ago 2018-06-22 5:33:39 pm	
81.37	9 days ago 2018-06-22 5:33:21 pm	
87.22	9 days ago 2018-06-22 5:33:03 pm	
87.22	9 days ago 2018-06-22 5:32:45 pm	
87.22	9 days ago 2018-06-22 5:32:26 pm	
84.26	9 days ago 2018-06-22 5:32:08 pm	
84.26	9 days ago 2018-06-22 5:31:50 pm	
87.22	9 days ago 2018-06-22 5:31:32 pm	
90.25	9 days ago 2018-06-22 5:31:14 pm	
113.36	9 days ago 2018-06-22 5:30:56 pm	
84.26	9 days ago 2018-06-22 5:30:37 pm	
90.25	9 days ago 2018-06-22 5:30:19 pm	
90.25	9 days ago 2018-06-22 5:29:58 pm	
96.50	9 days ago 2018-06-22 5:29:40 pm	
175.16	9 days ago 2018-06-22 5:28:46 pm	
232.22	9 days ago 2018-06-22 5:28:38 pm	
148.33	9 days ago 2018-06-22 5:28:38 pm	
293.59	9 days ago 2018-06-22 5:28:37 pm	

The SMS Message generated by the module when the concentration of the gases exceed the soft threshold is indicated by the image below.



ADVANTAGES OF THE PRESENT INVENTION OVER EXISTING TECHNOLOGIES

Different people are affected by asthma due to different causes. We provide customized solution for each customer by finding out which parameter triggers asthma in a particular person. This has never been ventured before. Nowadays, air quality monitoring systems exist, but this doesn't help an asthmatic patient to recover/prevent an attack from happening. What we do is a more personalised solution which can prevent asthma attacks. So, it basically acts an early warning system. Since an asthma takes 14-16 minutes to get triggered, our device will send an alert message to the phone in less than two minutes time. This gives the asthmatic to move away from the place helping them to avoid an athma attack. This usage can be extended for COPD patients as well.

UNIQUE FEATURE OF THE INVENTION

- Portable
- Customized solution
- Personalised solution
- Light weight
- Low cost
- Scalable hardware platform

Potential interface between the user, doctors, researchers and pharmaceutical industries enabling provision of personalised solution (for the user), patients (for doctors and industries) and data for analysis and research (Industries and researchers).