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Modular Sensor System for Urban Air Pollution Monitoring

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Abstract : *Air pollution attracts extensive attention globally due to its critical impacts on human life. Monitoring systems providing real-time micro-level pollution information have been developed to provide authorities with data to mitigate these impacts. However current systems are usually application-specific with fixed hardware and software configurations. They are inconvenient in maintenance, infeasible in reconfiguration, and expandable in sensing capabilities. This paper proposes a novel Modular Sensor System (MSS), which aims at tackling these issues by adopting the proposed ZigBee module as MSS Compactible. A compact MSS senor node with driver circuit and single ZigBee module modular sensor system (MSS) compatibility is implemented and evaluated. Results indicate that MSS sensor node can be deployed in different scenarios while dynamically adapting to reconfiguration and monitoring CO content at low concentration levels with high energy efficiency. We anticipate that MSS is able to relax the efforts on system maintenance, adaptation, and evolution in real-life large-scale deployment situation.*

Keywords: *Modular sensor system, ZigBee, Carbon Monoxide.*

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I. Introduction

With the fast development of the industrialization and urbanization process in the world, environmental pollution is now a common problem in most of the countries. Environmental pollution includes; air pollution, water pollution and soil pollution. Air pollution can be defined as the presence of contaminants or pollutant substances in the air that interfere with human health or welfare, or produce other harmful environmental effects [1]. Air pollution attracts extensive attention worldwide due to its tremendous impacts on human health, global environment and economy [2], [3]. These pollutant substances usually result from vehicle emissions, Industrial emissions and volatile organic compounds. The health issues caused by air pollutants are difficulty in breathing, coughing and aggravation of existing respiratory and cardiac conditions. The World Health Organization states that 2.4 million people die each year from causes directly attributable to air pollution, with 1.5 million of these deaths attributable to indoor air pollution [4]. Based on the fact mentioned above, there is a need to focus on air pollution monitoring activities. Due to the rapid development of communication technology, network technology and remote sensing technology, there is a trend that air pollution monitoring system is often designed in wireless mode [5]. Conventional monitoring systems have been deployed to provide authorized information for urban management and environmental improvement. These systems have extremely low spatial and temporal resolutions and are inadequate for monitoring personal and acute exposures to air pollutants [6], [7]. Thanks to the advance in technology, real-time air pollution information with high spatio-temporal resolution and in-time personal acute exposure warnings are available in next generation air monitoring systems [8] by deploying large numbers of stationary, wearable, or vehicular sensor nodes in field.

However, state-of-the-art systems providing real-time micro-level air pollution information are usually application- specific with fixed hardware and software configurations [9], [10]. Their flexibilities in maintenance, reconfiguration, and deployment are limited. In this paper, a Modular Sensor System (MSS) is proposed to address these issues. The major contributions of this paper are:

- A Modular Sensor System Architecture uses ZigBee module as wireless senor network and reconfigurable availability.
- Instead of transformer, 12-volt AC power supply is used which will reduce the size of board.
- MQ7 sensor is used to sense the CO content in environment, provide accurate range of CO content.

- Design, implementation, and evaluation of a compact MSS sensor node with driver circuit to connect the receiver module to computer through USB and single ZigBee module MSS compatibility, which is easy to use and maintain.
- Power supply section as in build LM71117 3.3V regulator for ATmega16 microcontroller and 7805 3.3V regulator for ZigBee module and bridge rectifier is used.
- MATLAB software is used for real time plot of CO content in graph.

II. Literature Survey

Due to recent technological advances, the construction material for small and low cost sensors became technically and economically feasible. [11] Even though, Industrialization increase the degree of automation and at the same time it increases the air pollution by releasing the unwanted gases in environment especially in industrial areas like Visakhapatnam. In order to implement the project, we selected four areas to deploy the application in Visakhapatnam. To detect percentage of pollution, we used the array of sensor to measure gas quantity in the physical environment in surrounding the sensor and convert them into an electrical signal for processing. Such a signal reveals some properties about interested gas molecule. A huge number of these sensors nodes can be networked in many applications that require unattended operations create a wireless sensor network. Wireless sensors are devices that range in size from a piece of glitter to a deck of cards. Integration of various components create the air pollution monitoring system.

They are functionally composed of:

A Sensing unit that is designed and programmed to sense gas pollutants in air in four busy areas in Visakhapatnam. Some common examples of properties or parameters that are monitored are light, temperature, humidity, pressure, etc. a converter that transforms the sensed signal from an analog to a digital signal. A Processing Unit in the Microcontroller, process the signals sensed form sensor with help of embedded memory, operating system and associated circuitry. A Radio component that can communicate the sink node or ZigBee router which collects the sensed pollution gas level from sensor node and forwards to pollution server which is in our campus. Powering these components is typically one or two small batteries. There are also wireless sensors utilized in applications that use a fixed value, wired power source and do not use batteries as a power source. In an external environment where the power source is batteries, wireless sensors are placed in an area of interest that is to be monitored, either in a random or known fashion. The sensors self-organize themselves in a radio network using a routing algorithm, monitor the area for measure the gas levels in air, and transmit the data to a central node, sometimes called a pollution server or base station (interfaced with coordinator), or sink node (interfaced with router), that collects the data from all of the sensors. This node may be the same as the other detection nodes, or because of its increased requirements, may be a more sophisticated sensor node with increased power. The most advantage of wireless sensors is that they may be implemented in an environment for extended over a time period, continuously detecting the environment, without the need for human interaction or operation.

III. HARDWARE REQUIREMENT'S

3.1 Step Down Transformer

Fig 3.1 Step Down Transformer

A step-down transformer has less turns on the secondary coil that the primary coil. The induced voltage across the secondary coil is less the applied voltage across the primary coil or in other words the voltage is "stepped-down". Transformers are very efficient. If it is assumed that a transformer is 100% efficient (and this is a safe assumption as transformers may be up to 99% efficient) then the power in the primary coil has to be equal to the power in the secondary coil, as per the law of conservation of energy.

Power in primary coil = Power in secondary coil

Primary coil p.d. x primary coil current = Secondary coil p.d. x secondary coil current

$$V_P \times I_P = V_S \times I_S$$

So if the potential difference is stepped up by a transformer then the current is stepped down by roughly the same ratio. In the case of the potential being stepped down by the transformer then the current is stepped up by the same ratio.

3.2 Electrolytic Capacitor

Fig 3.2 Electrolytic Capacitor

All electrolytic capacitors (e-caps) are polarized capacitors whose anode (+) is made of a particular metal on which an insulating oxide layer formed by anodization, acting as the dielectric of the electrolytic capacitor. A non-solid or solid electrolyte which covers the surface of the oxide layer in principle serves as the second electrode (cathode) (-) of the capacitor. Due to their very thin dielectric oxide layer and enlarged anode surface, electrolytic capacitors have—based on the volume—a much higher capacitance-voltage (CV) product compared to ceramic capacitors or film capacitors, but a much smaller CV value than electrochemical supercapacitors. The large capacitance of electrolytic capacitors makes them particularly suitable for passing or bypassing low-frequency signals up to some mega-hertz and for storing large amounts of energy. They are widely used for decoupling or noise filtering in power supplies and DC link circuits for variable-frequency drives.

3.3 LM117 Regulator

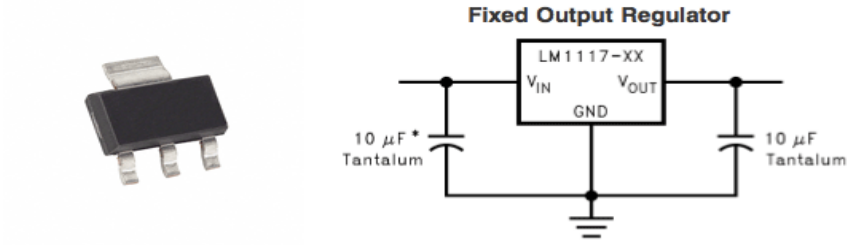

Fig 3.3 LM1117 Regulator

The LM1117 is a low dropout voltage regulator with a dropout of 3.3 V at 800 mA of load current.
The LM1117 is available in an adjustable version, which can set the output voltage from 1.25 to 13.8 V with only two external resistors. In addition, it is available in five fixed voltages, 1.8 V, 2.5 V, 3.3 V, and 5 V. The LM1117 offers current limiting and thermal shutdown. Its circuit includes a Zener trimmed bandgap reference to assure output voltage accuracy to within ±1%. A minimum of 10-µF tantalum capacitor is required at the output to improve the transient response and stability.

3.4 7805 Regulator

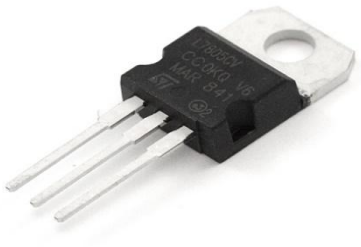

Fig 3.4 7805 Regulator

7805 is a voltage regulator integrated circuit. It is a member of 78xx series of fixed linear voltage regulator ICs. The voltage source in a circuit may have fluctuations and would not give the fixed voltage output. The voltage regulator IC maintains the output voltage at a constant value. The xx in 78xx indicates the fixed output voltage it is designed to provide. 7805 provides +5V regulated power supply. Capacitors of suitable values can be connected at input and output pins depending upon the respective voltage levels.

3.5 ATmega16 Microcontroller

Fig 3.5 ATmega16 Microcontroller

ATmega16 is an 8-bit high performance microcontroller of Atmel's Mega AVR family with low power consumption. Atmega16 is based on enhanced RISC (Reduced Instruction Set Computing, Know more about RISC and CISC Architecture) architecture with 131 powerful instructions. Most of the instructions execute in one machine cycle. Atmega16 can work on a maximum frequency of 16MHz. ATmega16 has 16 KB programmable flash memory, static RAM of 1 KB and EEPROM of 512 Bytes. The endurance cycle of flash memory and EEPROM is 10,000 and 100,000, respectively. ATmega16 is a 40 pin microcontroller. There are 32 I/O (input/output) lines which are divided into four 8-bit ports designated as PORTA, PORTB, PORTC and PORTD. ATmega16 has various in-built peripherals like USART, ADC, Analog Comparator, SPI, JTAG etc. Each I/O pin has an alternative task related to in-built peripherals.

3.6 MQ7 Sensor

Fig 3.6 MQ7 Sensor

This is a simple-to-use Carbon Monoxide (CO) sensor, suitable for sensing CO concentrations in the air. The MQ-7 can detect CO-gas concentrations anywhere from 20 to 2000ppm. Sensitive material of MQ-7 gas sensor is SnO2, which with lower conductivity in clean air. It make detection by method of cycle high and low temperature, and detect CO when low temperature (heated by 1.5V). The sensor's conductivity is higher along with the gas concentration rising. When high temperature (heated by 5.0V), it cleans the other gases adsorbed under low temperature. With the use of simple electro circuit, convert change of conductivity to correspond output signal of gas concentration. MQ-7 gas sensor has high sensitity to Carbon Monoxide. The sensor could be used to detect different gases contains CO, it is with low cost and suitable for different application.

3.7 LCD Display

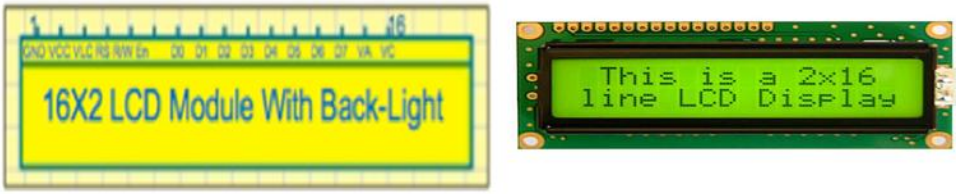

Fig 3.7 LCD Display

The most common type of LCD controller is HITACHI4470. This provides a relatively simple interface between a processor and LCD. This LCD having 16 characters and 2 lines characteristics.

- Pin no 1 of this display is connected to the ground.
- Pin no 2 is connected to the VCC+5 volts.
- Pin no.3 contrast adjustment pin. It is done by using PR4 variable resister 10k.
- Pin no 7 to 14 are data pins.
- Pin no 5 is read, write pin.

3.8 ZigBee Transceiver Model

Fig 3.8 ZigBee Transceiver Model

ZigBee is the most popular industry wireless mesh networking standard for connecting sensors, instrumentation and control systems. ZigBee, a specification for communication in a wireless personal area network (WPAN), has been called the "Internet of things." Theoretically, your ZigBee-enabled coffee maker can communicate with your ZigBee-enabled toaster. ZigBee is an open, global, packet-based protocol designed to provide an easy-to-use architecture for secure, reliable, low power wireless networks. ZigBee and IEEE 802.15.4 are low data rate wireless networking standards that can eliminate the costly and damage prone wiring in industrial control applications. Flow or process control equipment can be place anywhere and still communicate with the rest of the system. It can also be moved, since the network doesn't care about the physical location of a sensor, pump or valve.

3.9 USB ZigBee Adapter

Fig 3.9 USB ZigBee Adapter

ZigBee is a low power, wireless mesh network standard, largely used in the areas of home automation, medical data collection and industrial control. The USB ZigBee Adapter connects a PC or any USB capable host to a ZigBee network. At the core of the USB ZigBee Adapter is the ZigBee module from Digi, which implements the ZigBee stack. Once connected to the PC, the USB ZigBee Adapter is visible as a virtual COM port. The user can interact with the ZigBee stack, by sending commands through the virtual COM port.
The USB ZigBee Adapter also doubles up as an ZigBee Module Programmer for firmware upgrades. It has following features
• USB Powered
• Built in +3.3V regulator for ZigBee module

• ZigBee ZB and -PRO ZigBee ZB compatible
• LEDs for TX/RX and ZigBee state
• Debug LED and Key
• Local and remote loopback

IV. Figures and Tables

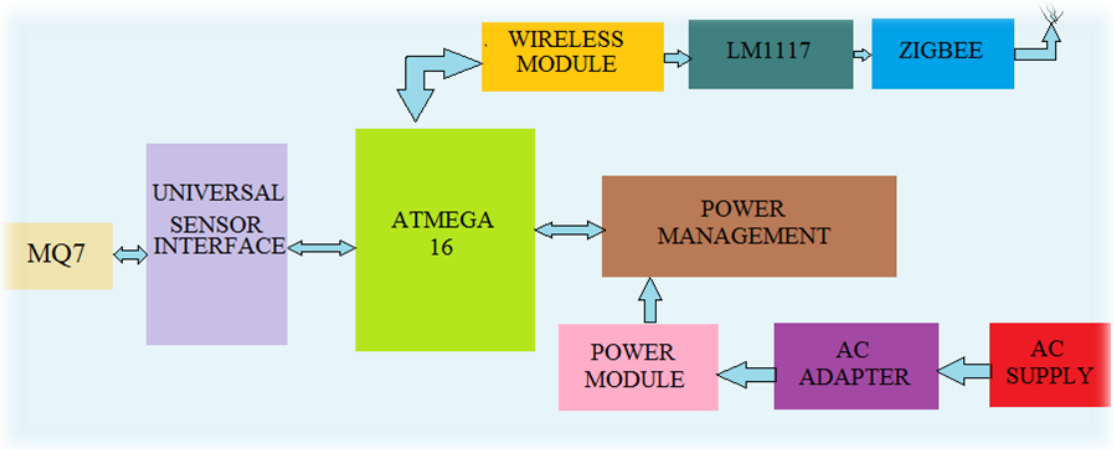

Figure.a. Transmitter Module

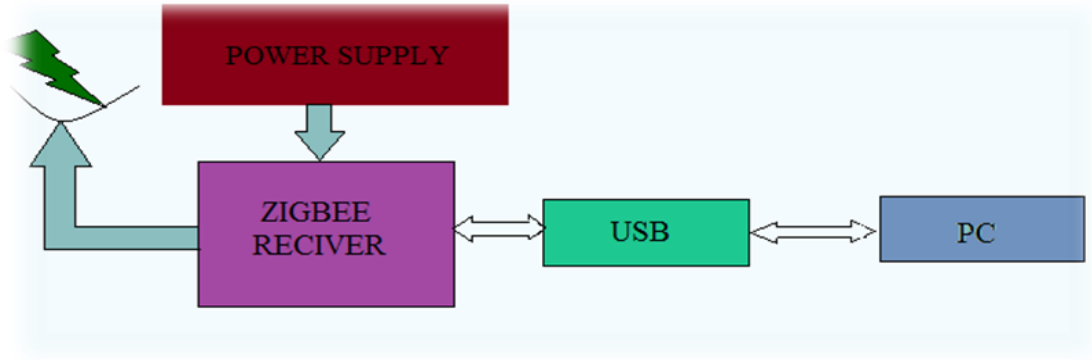

Figure.b. Receiver Module

Table.1. *Comparison table between sensed voltage and percentage of CO content*

Output Voltage	Air Quality (%)
0.78	0
0.85	0
0.96	0
1.05	0
1.17	0
1.43	0
1.65	4.28
1.75	7.142
1.86	10.28
1.99	13.61
2.16	18.85
1.35	24.28
1.55	30
2.76	36
2.91	40.28
3.09	45.52
3.42	54.85
3.56	58.85
4.12	74.85

Fig ii: Receiver Section

Initially architecture to define nodes and their interaction is developed using atmega16microcontroller MQ7 sensor, power supply module, ZigBee transceiver. The MQ7 sensor must be preheated up to 5Vto gain ability to sense. After preheating process MQ7 sensor senses for atmosphere and collect carbon monoxide(CO) in the readings from a region of interest in the voltage form. The real time sensed voltage by sensor is matched with the predefined values of percentage of carbon monoxide content in the atmosphere that is stored in atmega16microcontroller which decides the air quality as shown in fig(iii). Collaboration among thousands of nodes to collect readings and transmit them to a ZigBee receiver all the while minimizing the number of duplicates and invalid values. We use of appropriate data aggregation to reduce the power consumption during transmission of large amount of data from ZigBee transmitter. Visualization of collected data from ZigBee reviver along with statistical and user-friendly tool such as LabVIEW. Provision of an index to categorize the various levels of air pollution, with associated colors to meaningfully represent the seriousness of air pollution. Generation of reports on a daily or monthly basis as well as real-time notifications during serious states of air pollution for use by appropriate authorities.

V. Result

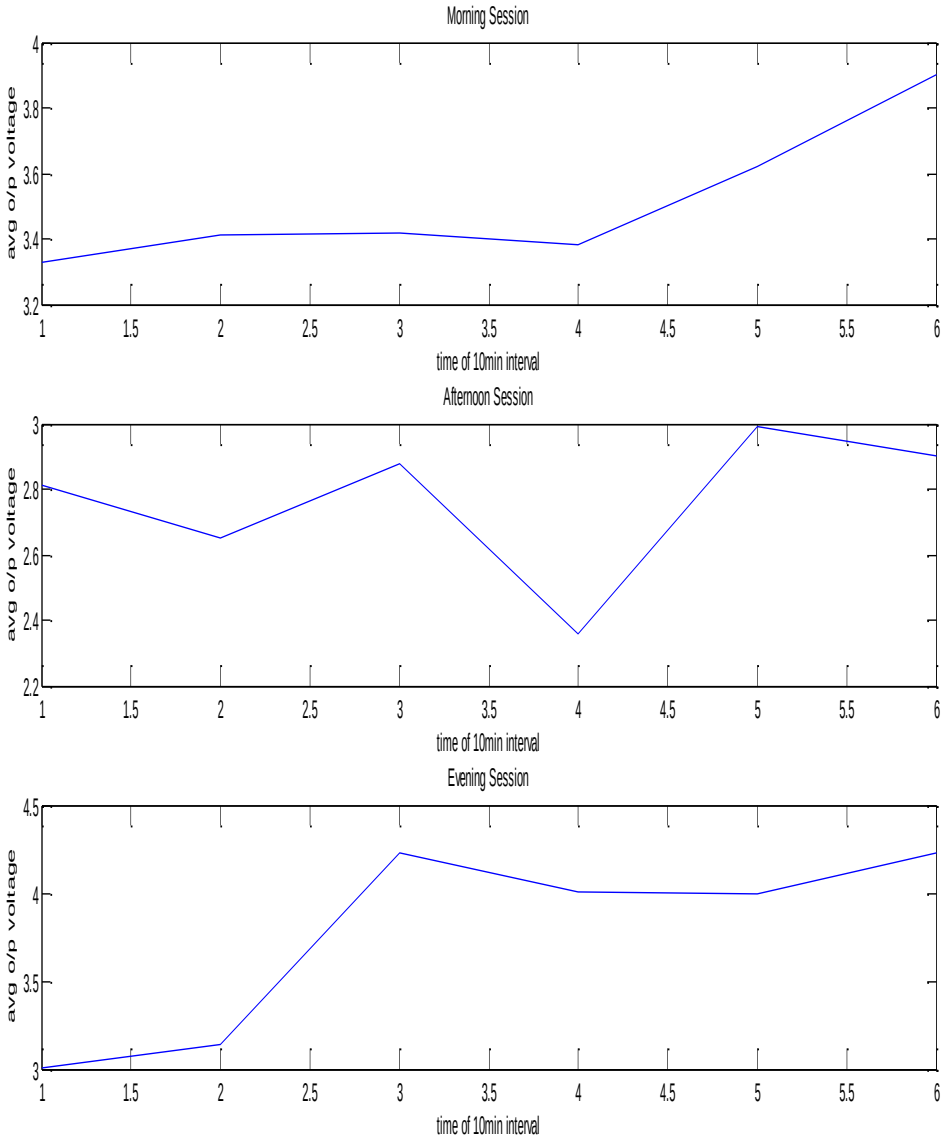

Fig 5.1 one-day graph

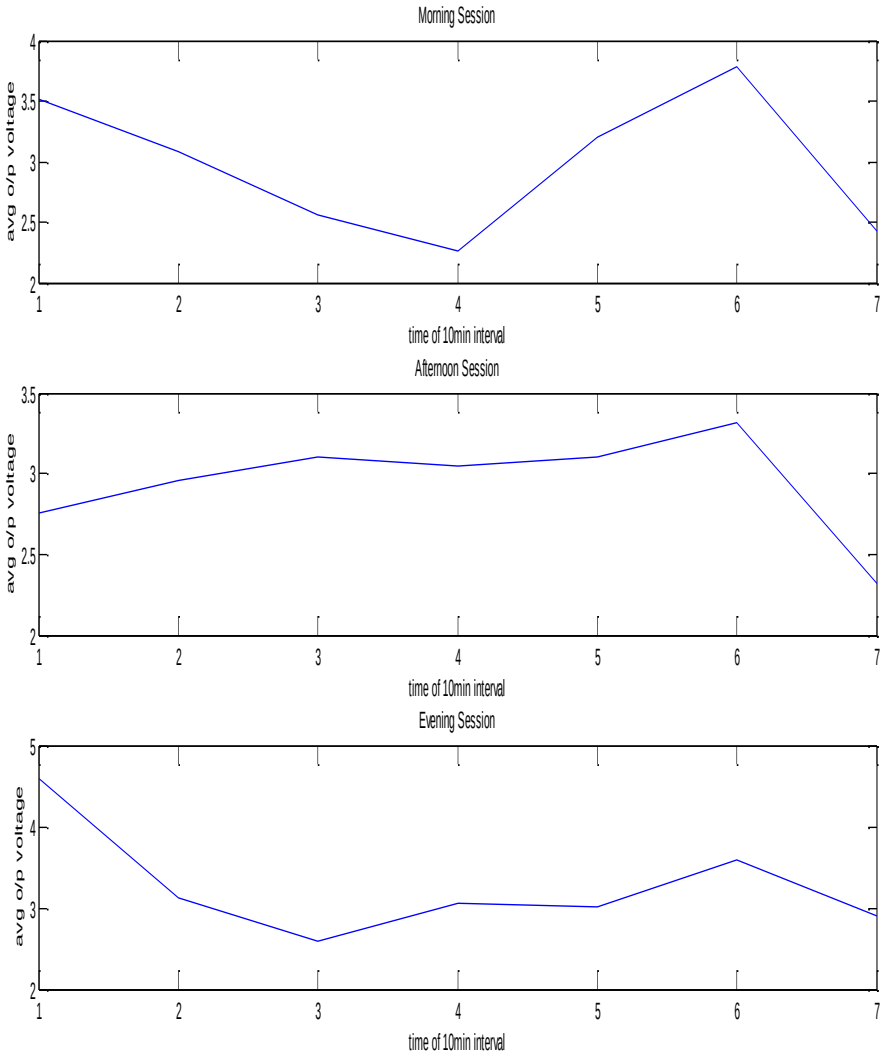

Fig 5.2 Graph Representation of Average of each Days in a Week

VI. Conclusion

The modular sensor system is used to collect pollutant gases such as CO2, CO, NO2 &SO2 from environment. But in this project the system is designed such as it has to sense the CO. The pollution data from various several that make this data available to government authority. The data shows the pollutant level. Pollutions will be more where the population are more. So we are expecting the result of surveying the content of carbon monoxide (CO) in the particular areas where traffic is more and tabulate an accurate data of it. After the couple of hour's delay, we will be surveying at the same area. But there will variation of content of carbon monoxide (CO) compared to an initial value. We here by conclude that with the help of above survey record suitable measures can be implemented on controlling of carbon monoxide in atmosphere "This is one of the concepts which help the country in controlling air pollution by contributing to SWATCHA BHARATH program"

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