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Monitoring of Hazardous Gases in Process Industries Through Internet

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***Abstract*—Monitoring is the first step for safety. In our day-to-day life there are many industries working with various hazardous chemical gases and the workers are often exposed to these gases. The unexpected accident cause a great impact to human lives and properties. To avoid these situations we need to develop an Automatic Toxic Gases Detection and Alerting System. The existing detection systems are available to sense only a particular gas and they use GSM technology to indicate the critical situations. The drawback is that the detection system can send a message to only one person. The proposed system is made up of monitoring and alerting system through Internet of Things (IoTs). In this the dangerous, toxic and flammable gases such as Hydrogen Sulfide gas, Carbon Monoxide gas, Ammonia gas, and Methane gas are sensed using individual gas sensors and an Arduino UNO controller. The concentration of all gases values are displayed in ppm using a Liquid Crystal display in the plant premises; when the value exceeds the limited range then an alarm is put on. The advancement in this project is the values are constantly uploaded to the internet by using Ethernet module with an Arduino controller. The Internet of Things (IoTs) provides a proper access to values by an authorized persons and governmental organization. A database is also maintained, this helps to know the status of an industry. The timely sensing of chemical toxic gases offers a quick response on an emergency situation and therefore leading faster diffusion of the critical situation.**

Keywords—Hazardous gases, monitoring, IoTs, Arduino UNO, Ethernet module

I. INTRODUCTION

Safety and health management is one of the vital constituents of industrial activities because most of the operational conditions, chemicals and end products associated with industrial production are well-known to pose serious safety and health threats to the workers and environment. The problems related to air quality monitoring are important issues of the current research activity. In fact, a key component in many process controls, product development, environmental monitoring etc. is the measurement of concentration of one or the other gaseous components. The most polluting industries in the world are pesticides pollution from agriculture and storage, waste water treatment in industries, tanning industries, and coal mining. Industrial plants, such as chemical works and metal-smelting plants, release SO_2, H_2S, NO_2, and CO into the atmosphere. Tall chimney stacks may be used to carry gases and particles to a high altitude and thus avoid local pollution, but the pollutants return to Earth, sometimes hundreds of kilometer from the original source. The identified hazardous gases are Hydrogen Sulfide (H_2S), Carbon Monoxide (CO), Ammonia (NH_3), and Methane (CH_4) gas. The exposure to these gases gives a severe health hazards to the humans. Inorder to avoid high exposure a monitoring system should be developed.

II. LITERATURE REVIEW

Every day synthetic, toxic chemicals are released into the environment. It affects our water, land and air. These pollutants may cause serious health effects such as birth defects, development disorders, respiratory problems, cancer and in some cases can lead to death. Apart from this, it can also have adverse effect on wildlife and environment. The main polluting industries in India where hazardous gases evolve are waste water treatment plant, tanneries, coal mining industries, textile dye processing, and pesticide pollution. Consider few industries and their problem.

- Each year millions of people are affected by the toxic chemicals, primarily iron, limestone, pyrite and zinc that are released into the air by the dozens of lead smelting sites around the world. Lead smelting uses furnaces and other chemical agents to remove impurity from lead ores. Lead Smelting puts approximately 2.5 million people at risk at 70 polluted lead smelting sites worldwide, according to Blacksmith Institute.
- Pesticides are substances necessary for agriculture to destroy targeted pests. An approximate 2 million metric tons of pesticides are used annually on fields. As a result, millions of tons of pesticides are dumped every year on our fields. Unfortunately, the health effects pesticides have on us are disastrous, from simple skin irritation to hurting to nervous system to even causing cancer. Apart from this, stockpiles of old and outdated pesticides add to the trouble. Most of the farmers are illiterate and use expired products. An estimated six to nine million metric tons of such pesticides are improperly stored.
- Tanning industries are primarily used to turn animal hides into leather for consumers, in places called tanneries, which are primarily centered in South-East Asia. Such tanneries are still operating with little control and produce daily 7.7 million litres of waste water and 88 million tons of solid waste and hazardous gases. Cr IV is dangerous and can cause health problems as in respiratory and heart failure and cancer in the brain and kidneys.

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A. Existing Methods

The existing methods uses various technology for identifying the hazardous gases and regular monitoring in an industry or for environment takes technologies such as GSM, ZigBee, WSN. Let us consider the different existing systems as follows.

- The system measures the gases values using different sensors and transmit the values using RFID tag. The RFID tag is very small equipment, it can be used with any controller. The components are gas sensors, humidity sensor, reader and server. The transmitter and receiver has an RFID tag which uses radio frequency to exchange the data. The concentration values can be classified at various levels. They are safe stage, warning stage and risk stage. The software shows the concentration values in graph format. The workers can take necessary measures according to the concentration level. The disadvantage of the system is that it can send data to only single RFID receiver tag.
- The gas leakage security system is an embedded system for hazardous gas detection and alerting has been proposed where the alarm is activated immediately, if the gas concentration exceeds normal level. Bhopal gas tragedy was an example of gas leakage accident in India. This was world's worst gas leakage Industrial accident. Gas leakage detection is not only important but stopping leakage is equally essential. This existing system provides a cost effective and highly accurate system, which not only detect gas leakage but also alert (Beep) and turn off main power and gas supplies, and sends a SMS. GSM module is used which alert the user by sending an SMS. The disadvantage in this method is that the information can be intimated to a single user only.
- The trend in air pollution monitoring system is often designed in Wireless sensor network have been rapidly developed during recent years. Starting from military and industrial controls, its advantages include the liability, simplicity, and low cost. Based on these advantages, it is now being applied in environmental monitoring. In air pollution monitor applications, the designed system is a WSN based air pollution monitoring system using ZigBee networks for City. The ZigBee network can cover a certain area of data exchange. They focus on implementation of air pollution monitoring system, and developed an integrated wireless sensor board which employs CO2, NO2/NH3 temperature sensor, atmega16 micro-controller, database server and a ZigBee module.

B. Hydrogen Sulfide Gas

Hydrogen sulfide is a colorless, flammable, hazardous gas with a rotten egg smell. It is both an irritant and a chemical asphyxiant with effects on both oxygen utilization and the central nervous system. Its health effects can vary depending on the level and duration of exposure. Repeated exposure can result in health effects occurring at levels that were previously tolerated without any effect. The health effects are shown in following table I.

TABLE I. HUMAN HEALTH EFFECTS OF HYDROGEN SULFIDE AT VARIOUS CONCENTRATIONS

Concentration (ppm)	***Sign and Symptoms***
0.008	Odour threshold
2	Bronchial constriction in asthmatic individuals
4	Increased eye complaints
5 or 10	Increased blood lactate concentration Decreased oxygen uptake
20	Fatigue, loss of appetite, headache, irritability, poor memory, dizziness
>100	Olfactory paralysis
>400	Respiratory distress
>500	Death

C. Carbon Monoxide Gas

Carbon monoxide is a poisonous, colorless, odorless, and tasteless gas. CO is a common industrial hazard resulting from the incomplete burning of natural gas and any other material containing carbon such as gasoline, kerosene, oil, propane, coal, or wood. Forges, blast furnaces and coke ovens produce CO, but one of the most common sources of exposure in the workplace is the internal combustion engine. Most of the industries work with boilers for heating purpose, this consumes high amount of wood products which also releases CO during burning. The exposure to carbon monoxide gives health effects at various concentration of CO, which is shown in table II.

TABLE II. HUMAN HEALTH EFFECTS OF CARBON MONOXIDE AT VARIOUS CONCENTRATIONS

Concentration (ppm)	Sign and Symptoms
35	Headache and dizziness within 6-8 hours of constant exposure
100	Slight headache in 2-3 hours
800	Dizziness, nausea, and convulsion within 45 min; insensible in 2 hours
1600	Headache, tachycardia, nausea, dizziness within 20 minutes; death within 2 hours
6400	Headache and dizziness in 2-3 minutes. Convulsion, respiratory arrest and death in less than 20 minutes.
12800	Unconsciousness after 2-3 breath. Death in less than 3 minutes.

D. Methane Gas

Methane is a colorless, tasteless gas which is the primary component of natural gas. It is present beneath the earth's surface in vast quantities, but levels in the atmosphere are relatively low. Methane is produced naturally by volcanoes, ruminant animals such as cattle and sheep, decaying plants, extraction of natural gas, coal mining and waste disposal such as landfills. The health effects of methane gas is shown in table III.

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TABLE III. HUMAN HEALTH EFFECTS OF METHANE GAS AT VARIOUS CONCENTRATIONS

Concentration (ppm)	Sign and Symptoms
20-100	Irritation to eyes
400	Irritation to mucous surface
700	Immediately irritating to eyes and throat
5000	Respiratory edema, rapid suffocation
10000	High risk of death

E. Ammonia Gas

Ammonia gas is a pungent smelling gas. It is a basic nutritional need for all terrestrial organisms. It act as a precursor to food and fertilizers. Ammonia is a primary building block of various pharmaceuticals, pesticides and cleaning products. The ammonia gas presences can be found in various fossil decaying products.

Ammonia is transported in bulk as a pressurized gas. Ammonia is used as a refrigerant gas, for purification of water supplies, and in the manufacture of plastics, explosives, textiles, pesticides, dyes and other chemicals. Exposure to ammonia may occur in industrial settings or following an accidental spill or leak during transport. The health effects of ammonia gas on humans is shown in table IV.

TABLE IV. HUMAN HEALTH EFFECTS OF AMMONIA GAS AT VARIOUS CONCENTRATIONS

Concentration (ppm)	Sign and Symptoms
50	Irritation to eyes, nose and throat (2 hours exposure)
100	Rapid eye and respiratory tract irritation
250	Tolerable by most people (30–60 minutes exposure)
700	Immediately irritating to eyes and throat
>1500	Pulmonary disorder, coughing, laryngospasm
2500-4500	Fatal (30 minutes exposure)
5000-10000	Rapidly fatal due to airway obstruction, may also cause skin damage

III. PROPOSED SYSTEM

The proposed system is placed in an industry where the hazardous gases have to be monitored. The individual sensors are placed to read the range of gaseous concentration in ppm. Each sensor is sensitive to its own specific gas. These sensor values are read by the microcontroller, and then it is programmed to monitor the range of all gases. When the concentration of any gas exceeds its limit then the alarm is put on, simultaneously the concentration of all gases are displayed in the LCD display. This display gives a notification to workers working in the plant premises. A Local Area Network (LAN) port is also available in the Ethernet module which is connected to the controller so that the concentration of all gases are uploaded to a website constantly.

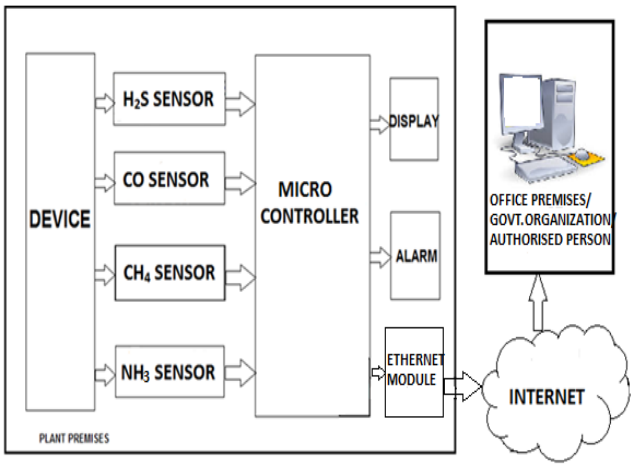

Figure 1. Block Diagram of the Proposed System

The conceptual diagram shows the concept of the proposed method, this is shown in Figure 1. The block diagram shows two important areas in industries they are Plant premises, Office premises. In plant premises the sensors are placed where the toxic gases are expected to evolve, in the occurrences of the gases their concentration is calculated in the form of voltages. The sensor converts the physical quantity into the voltages, when concentration increases the input voltage to microcontroller through sensor is also simultaneously increases. In office premises, the concentration of each gases are monitored in the website. The government sectors and health organizations having authority of analyzing the industrial status can also have a note on the website information.

IV. HARDWARE DESCRIPTION

A. Arduino UNO

The Arduino Uno is a microcontroller board based on the ATmega328. It has 14 digital input/output pins which 6 can be used as PWM outputs, 6 analog inputs, a 16 MHz crystal oscillator, a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with an AC-to-DC adapter or battery to get started. The ATmega328 processor can operate from a wide range of power-supply voltages, from 1.8V to 5.5V. This makes it well suited for battery-powered applications. ATmega328 chip can run up to 20MHz as operating frequency.

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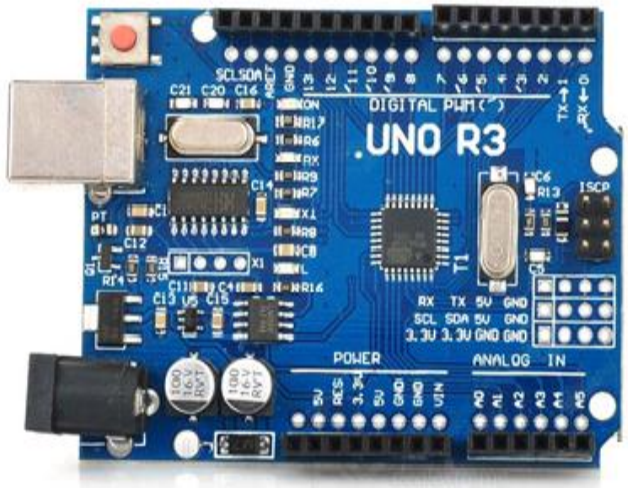

Figure 2. Arduino UNO R3 Model Board

The Arduino board contains various models, here Arduino UNO R3 model is used. The figure 2 Shows the Arduino board front view. The features of the Atmega chip is shown in the table 1. The AVR core combines a rich instruction set with 32 general purpose working registers. All the 32 registers are directly connected to the Arithmetic Logic Unit (ALU), allowing two independent registers to be accessed in one single instruction executed in one clock cycle. The technical specification of Arduino UNO board is shown in table V respectively.

TABLE V. TECHNICAL SPECIFICATION OF ARDUINO UNO BOARD

Parameters	Specification
Microcontroller	ATmega328
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limits)	6-20V
Digital I/O Pins	14 (of which 6 provide PWM output)
Analog Input Pins	6
DC Current per I/O Pin	40 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	32 KB of which 0.5 KB used by boot loader
SRAM	2 KB
EEPROM	1 KB
Clock Speed	16 MHz

B. Ethernet Controller Module

The ENC28J60 is a stand-alone Ethernet controller with an industry standard Serial Peripheral Interface (SPI) shown in figure 3. It is designed to serve as an Ethernet network interface for any controller equipped with SPI. The ENC28J60 meets all of the IEEE 802.3 specifications. It incorporates a number of packet filtering schemes to limit incoming packets. It also provides an internal DMA module for fast data throughput and hardware assisted IP checksum calculations. Communication with the host controller is implemented via two interrupt pins and the SPI, with data rates of up to 10 Mb/s. Two dedicated pins are used for LED link and network activity indication.

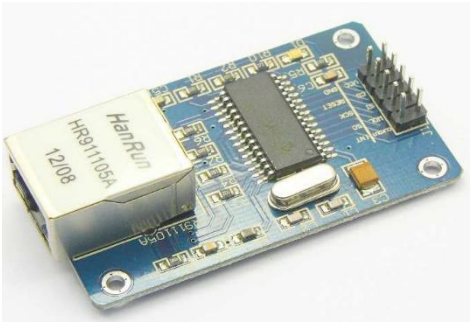

Figure 3. Ethernet Controller ENC28J60

The Ethernet Controller can be interfaced with the Arduino controller by a configuration the following is a table VI describing which pins on the Arduino should be connected to the pins on the ENC28J60 Ethernet Module.

TABLE VI. INTERCONNECTIONS BETWEEN ETHERNET CONTROLLER AND ARDUINO UNO R3

ENC28J60 Module	Arduino UNO
CS	D10
SI	D11
SO	D12
SCK	D13
RESET	RESET
INT	D2
VCC	VCC
GND	GND

C. Hydrogen Sulfide Sensor

Hydrogen sulfide gas can be sensed by a semiconductor sensor MQ136. The sensing element of gas sensors is a tin dioxide (SnO_2) semiconductor which has low conductivity in clean air. In the presence of a detectable gas, the sensors conductivity increases depending on the gas concentration in the air. A simple electrical circuit can convert the change in conductivity to an output signal which corresponds to the gas concentration as shown in figure 4. The concentration of detection is 10-200 ppm.

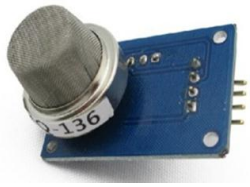

Figure 4. MQ136 Hydrogen Sulfide Sensor

D. Carbon Monoxide Sensor

Carbon Monoxide gas can be sensed by a semiconductor sensor MQ7. The sensing element of gas sensors is a tin dioxide (SnO_2) semiconductor which has low conductivity in clean air. In the presence of a detectable gas, the sensors conductivity increases depending on the gas concentration in the air. A simple electrical circuit can convert the change in conductivity to an output signal which corresponds to the gas concentration as shown in figure 5. The concentration of detection is 10-10000 ppm.

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Figure 5. MQ7 Carbon Monoxide Sensor

E. Ammonia Gas Sensor

Sensitive material of MQ137 gas sensor is SnO2, which with lower conductivity in clean air. When the target combustible gas exists the sensor's conductivity is higher along with the gas concentration rising. Please use simple electronic circuit, Convert change of conductivity to correspond output signal of gas concentration. MQ137 gas sensor shown in figure 6 has high sensitivity to Ammonia, also to other organic amine. The sensor could be used to detect different gas which contains Ammonia, it is with low cost and suitable for different application and sense 5-500 ppm.

Figure 6. MQ137 Ammonia Gas Sensor

F. Methane Gas Sensor

Sensitive material of MQ-4 gas sensor is SnO2, which with lower conductivity in clean air. When the target combustible gas exist, the sensor's conductivity is higher along with the gas concentration rising. The simple electronic circuit as shown in figure 7, Convert change of conductivity to correspond output signal of gas concentration. MQ-4 gas sensor has high sensitivity to Methane, also to Propane and Butane. The sensor could be used to detect different combustible gas, especially Methane, it is with low cost and suitable for different application and can sense 300-10000 ppm.

Figure 7. MQ4 Methane Gas Sensor

G. Display and Alarm Unit

A LCD display is placed in the industries for alerting the concentration of the gases to workers. This uses a general 16X2 LCD display. A buzzer is installed in this system to alert at a sudden increase in the concentration of gas above its prescribed limit.

V. SOFTWARE DESCRIPTION

A. *Installing the Arduino IDE on Windows*

The Arduino IDE runs on all the latest versions of Microsoft Windows, such as Windows XP, Windows Vista, and Windows 7. Installing the software is easy, because it comes as a self-contained ZIP archive so it does not even need an installer. Download the archive, and extract it to a location of choice. Install drivers for the Arduino USB port and this process depends on the Arduino board used. After the drivers have been installed, start the Arduino executable from the archive's main directory by double-clicking it.

B. Programming an Arduino UNO

The Arduino board can be programmed using the Arduino IDE software. By opening the Arduino IDE software the editorial window open. In that there are two important part they are setup part and main loop. The Arduino ports such as input, output, and constant functions are defined in setup part and looping actions are coded in main loop. The coded program is compiled and checks for an error and warning. After a successful debugging the code is fused in controller through an upload option.

VI. CONCLUSION

In this proposed paper a hazardous gas monitoring embedded system designed using Internet of Things to detect toxic and flammable gases from industrial environment. The individual gas has its own range of risk, they are identified using advanced sensors. This system gives an instantaneous alarm during the excessive emission of hazardous gases. The current value of all gases in their concentration are display in an LCD display and in internet webpage. Hence the status of the process industries can be monitored and leads to the effective management of adverse condition. The system is more flexible and low cost so that it can be implemented in any of the process industries.

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