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An Efficient Interface for Monitoring Air Pollution by Using Micro-Controller Based Sensors

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ABSTRACT: The industry of monitoring air pollution always struggle with synchronizing itself with technology growth. In this paper, we consider design of protocol using sensors connected to a micro-controller based system launched in any exterior remote location. The main objective is to investigate the available feasibility studies in the air pollution control and present in the format suitable for micro-controller. This research direction contributes to optimizing the solution for social constraints and spread of pollution.

KEYWORDS: Air Pollution, PIC16F877A, TGS2442, TGS 4161, TGS 823, TGS2201, Gas Sensors

I. INTRODUCTION

The increase in the development of technology and the human race, we failed to take care about the surroundings in which we live in. Thus we polluted the environment and thereby reducing the quality of the place we live. Even though there are several aspects of pollution such as soil, air and water pollution, out of these air pollution acts as the serious aspect as the other can detected visually and by taste, but the polluted air cannot be detected as it can be odorless, tasteless and colorless. Hence there is a growing demand for the environmental pollution monitoring and control systems. In the view of the ever-increasing pollution sources with toxic chemicals, these systems should have the facilities to detect and quantify the sources rapidly. Toxic gases are one that causes serious health impacts, but are also used in industries in large quantities. These gases have to be monitored; such that increase in the normal level of them could be known and proper precaution measures can be taken. But the current systems available are not so portable and are costly and difficult to implement. The paper presents a prototype for measuring the levels of the main air pollutants NO2, NOx, CO, and CO2 in cities. So a protocol is designed using PIC 16F877 Microcontroller, for the purpose of measuring the levels of air pollution. The system also supports to provide real-time monitoring of concentration of the gases which presents in the air. As this method is automatic the information can be given in time such that the endangering of human lives can be avoided.

II. AIR POLLUTION

Air pollution is the introduction into the atmosphere of chemicals, particulates, or biological materials that cause discomfort, disease, or death to humans, damage other living organisms such as food crops, or damage the natural environment or built environment. The atmosphere is a complex dynamic natural gaseous system that is essential to support life on planet Earth. Stratospheric ozone depletion due to air pollution has long been recognized as a threat to human health as well as to the Earth's ecosystems. A substance in the air that can be harmful to humans and the environment is known as an air pollutant. Pollutants can be in the form of solid particles, liquid droplets, or gases. In addition, they may be natural or man-made. Pollutants can be classified as primary or secondary. Usually, primary pollutants are directly emitted from a process, such as ash from a volcanic eruption, the carbon monoxide gas from a motor vehicle exhaust or sulfur dioxide released from factories. Secondary pollutants are not emitted directly. Rather, they form in the air when primary pollutants react or interact. An important example of a secondary pollutant is ground level ozone — one of the many secondary pollutants that make up photochemical smog. Some pollutants may be both primary and secondary: that is, they are both emitted directly and formed from other primary pollutants. Major primary pollutants produced by human activity include Sulphur Oxides(SO_x) ,Nitrogen Oxides(NO_x), Carbon Monoxide(CO), Carbon dioxide(CO_2), Ozone(O_3), Lead, Mercury and so on.

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A. *Sources of Air Pollution*

TABLE I
SOURCES OF AIR POLLUTION

Pollutant	Anthropogenic Sources	Health Effects	Environmental Effects
Ozone (O_3)	Secondary pollutant formed by chemical reaction of VOCs and NOx in the presence of sunlight.	Breathing problems, reduced lung function, asthma, irritates eyes, stuffy nose, reduces resistance to colds and infections, premature aging of lung tissue.	Damages crops, forests, and other vegetation; damages rubber, fabric, and other materials; smog reduces visibility.
Nitrogen Oxides (NOx)	Burning of gasoline, natural gas, coal, oil. (Cars are a major source of NOx.)	Lung damage, respiratory illnesses, ozone (smog) effects.	Ozone (smog) effects; precursor of acid rain which damages trees, lakes, and soil; aerosols can reduce visibility. Acid rain also causes buildings, statues, and monuments to deteriorate.
Carbon Monoxide (CO)	Burning of gasoline, natural gas, coal, oil.	Reduces ability of blood to bring oxygen to body cells and tissues.	Volcanic eruptions, while sporadic, are significant contributors to carbon monoxide in their local area. Fires of all types will also contribute to carbon monoxide in the atmosphere.
Volatile Organic Compounds (VOCs)	Fuel combustion, solvents, paint. (Cars are a major source of VOCs.)	Ozone (smog) effects, cancer, and other serious health problems.	Ozone (smog) effects, vegetation damage.
Particulate Matter	Emitted as particles or formed through chemical reactions; burning of wood, diesel, and other fuels; industrial processes; agriculture (plowing, field burning); unpaved roads.	Eye, nose, and throat irritation; lung damage; bronchitis; cancer; early death.	Source of haze which reduces visibility. Ashes, smoke, soot, and dust can dirty and discolour structures and property, including clothes and furniture.
Sulfur Dioxide (SO_2)	Burning of coal and oil, especially high-sulfur coal; industrial processes (paper manufacturing, metal smelting).	Respiratory illness, breathing problems, may cause permanent damage to lungs.	Precursor of acid rain, which can damage trees, lakes, and soil; aerosols can reduce visibility. Acid rain also causes buildings, statues, and monuments to deteriorate.
Lead	Combustion of fossil fuels and leaded gasoline; paint; smelters (metal refineries); battery manufacturing.	Brain and nervous system damage (esp. children), digestive and other problems. Some lead-containing chemicals cause cancer in animals.	Harm to wildlife and livestock.
Mercury	Fossil fuel combustion, waste disposal, industrial processes (incineration, smelting, chlor-alkali plants), mining.	Liver, kidney, and brain damage; neurological and developmental damage.	Accumulates in food chain.

B. *Causes of Air Pollution*

- We cause air pollution directly through our use of electricity, fuels, and transportation. We also cause air pollution indirectly, when we buy goods and services that use energy in their production and delivery. Most of this air pollution we cause results from the burning of fossil fuels, such as coal, oil, natural gas, and gasoline to produce electricity and power our vehicles. Carbon dioxide (CO2) is a good indicator of how much fossil fuel is burned and how much of other pollutants are emitted as a result. Combustion of fuel is one of the major causes of air pollution in urban areas. Burning of fossil fuels such as natural gas and gasoline leads to the emission of carbon dioxide and other gases, which deteriorate the quality of air, making it polluted.
- Increased level of carbon dioxide in the atmosphere is one of the prime causes of air pollution. Power plants, exhaust fumes of automobiles, airplanes and other human activities involving the burning of gasoline and natural gas are related to the emission of this greenhouse gas.

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- The chlorofluorocarbons (CFCs), a class of synthetic chemicals used in refrigerants and aerosol propellants, have caused hole in Earth's ozone layer. The use of this banned chemicals is related with the increasing levels of air pollution.
- Sulfur dioxide is one of the components of smog, which is related with contamination of the Earth's atmosphere. This synthetic chemical is the prime cause of acid rain.
- Air pollution is partially caused by the particulates formed by a variety of substances, such as dust, pollen and other organic materials.
- Increased road and air traffic is another reason related to the high level of air pollution.

Using carbon dioxide as an example, the average family in India causes air pollution in the following ways:

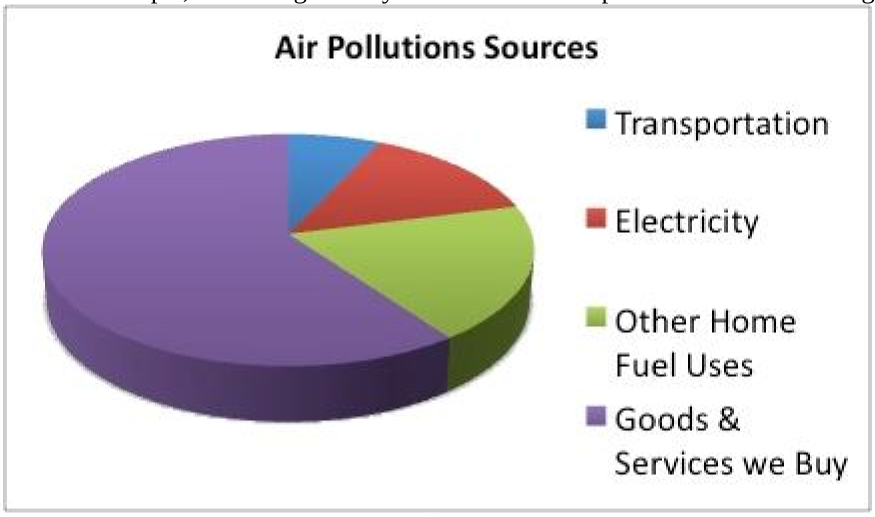

Fig. 1 Air Pollution Sources

C. *State of Air Pollution in Indian Cities*

Air quality data generated by the Central Pollution Control Board (CPCB) for 2007 under the National Air Quality Monitoring Programme (NAMP) presents deadly facts about air pollution levels in Indian cities.Centre for Science and Environment has analysed the official data to assess the state of air quality and trend in Indian cities. The most widely monitored pollutants in India are particulate matter (PM), nitrogen dioxide (NO_2), sulphur dioxide (SO_2), and on a limited scale carbon monoxide.
Some of the worst forms of air pollutions are found in Indian cities. The Central Pollution Control Board (CPCB) considers air to be ‘clean’ if the levels are below 50 per cent of the prescribed standards for pollutants. During 2007 only 2 per cent cities have low air pollution on the basis of PM_{10}. In about 80 per cent of cities (of a total of 127 cities/towns monitored under the NAMP) at least one criteria pollutant exceeded the annual average ambient air quality standards. This has serious public health implications. There are very few cities, which can be termed clean keeping PM_{10} levels (respirable particulates) as criteria however over the years SO_2 levels have fallen sharply in many cities but the NO_2 levels are increasing in many cities.

1) *PM10 trend:-* Almost half of the total cities monitored under NAMP have critical levels of PM_{10}. CPCB classifies cities as critically polluted if the levels of criteria pollutants are more than 1.5 times the standards. Levels up to 1.5 times the standards are labeled high. Levels that reach up to 50 per cent of the standards are moderate. And lower than that is low. In 2007 data of 121 cities has been analysed and only three cities Dewas, Tirupati, Kozhikode recorded low pollution level.Indian cities are reeling under heavy particulate pollution with 52 percent of cities (63 cities) hitting critical levels (exceeding 1.5 times the standard), 36 cities with high levels (1–1.5 times the annual standard) and merely 19 cities are at moderate levels, which is 50 per cent below the standard. The PM_{10} levels remain persistently high in the northern region. In the NCR towns Noida, Faridabad including NCT Delhi have high levels of PM_{10} and in past two years the levels have increased. Only in hill towns such as Shimla, Gajraula and Parwanoo have low PM_{10} levels. In western and eastern India, there is usually a mixed trend. Eastern cities, including Shillong, Angul, Rourkela and Howrah, show an increasing trend and in the west PM_{10} levels have declined in some cities like Ahmedabad, Solapur, Nagda and Jamnagar but increased in Mumbai, Kota and Satna.In southern India, though the cities generally have lower PM_{10} levels compared to the northern ones, some cities show an increase. In cities such as Hyderabad, Visakhapatnam, Tuticorin, and Bangalore there is an increasing trend. A sharp declining trend has been noted in Thiruvanthapuram, Kochi and Mysore during 2000-2007 PM10 levels are gradually reducing.

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2) *NOx trend:-* NOx (measured as NO_2) is emerging as the new national challenge and a growing problem. The NO_2 levels during 2007 at seven monitoring stations exceeded the annual average standard in residential areas and NO_2 level at one monitoring stations in industrial areas exceeded annual average standard. The seven monitoring stations in residential areas that exceeded the standard are located at Town Hall (82 microgram per cubic metre), Sarojini Nagar (65 microgram per cubic metre) in Delhi, Salt lake (66 microgram per cubic metre), Moulali (76 microgram per cubic metre), Minto Park (65 microgram per cubic metre), in Kolkata, Gandhi Maidan (67 microgram per cubic metre) in Patna and Ghuseri (68 microgram per cubic metre) in Howrah. One monitoring stations in industrial areas where annual average standard was exceeded is located at Bandhaghat 91 microgram per cubic metre, (Howrah).In North India, cities such as Delhi (where traffic areas record high levels and often exceed the standards), Dehradun, Yamunanagar and Ludhiana show a rising trend. Eastern cities, including Howrah, Kolkata, Dhanbad, Jamshedpur and Jharia, have much higher levels compared to northern cities. In many cities in this region the levels declined up to 2004 however there is an increasing trend observed again in past two years.Southern Indian cities show a rising trend especially in Visakhapatnam, Hyderabad and Thiruvanthapuram. Cities in western India are relatively better off with almost constant to declining NO_2 levels, though the levels indicate an increasing trend in Mumbai, Nagpur, Nashik, Pune and Chandrapur. Pune after showing high levels till 2003 showed sharp decline till 2005. One of the reasons attributed to lower levels being recorded in Pune is the shifting of the monitoring stations away from heavy traffic sites.

3) *SO_2 trend:-* Sulfur dioxide is not considered a problem in India any more. Its levels in most cities are already very low and declining. However, there are still some cities such as Khurja, Nashik, Jamshedpur and Chandrapur have moderate levels, the maximum levels was recorded at Khurja with 45 microgram per cubic meter.During 2007 National Ambient Air Quality Standard (NAAQS) (annual average) was not exceeded at any monitoring station in residential and industrial areas. SO_2 levels at 79 per cent of the monitoring stations in industrial areas and 93 per cent of the monitoring stations in residential areas were less than 20 microgramme per cubic metre. The highest concentration in residential area was observed at monitoring station located at Nashik and highest concentration in industrial area was observed at monitoring station located at Khurja (UP) during 2007, although SO_2 levels at none of the monitoring stations exceeded the annual average standard.

4) *Trend in big cities:* In the cities like Ahmedabad, Varanasi, Chennai, Pune, and Kolkata the PM10 levels have reduced in 2007 compared to 2002 levels. However in the cities like Mumbai, Faridabad, Lucknow, Bangalore and Delhi the PM_{10} annual average levels have increased in 2007 over 2002. The nitrogen dioxide levels in the cities like Solapur, Ahmedabad, Pune and Kolkata has reduced. According to CPCB, although various interventions have taken place to mitigate ambient NO2 levels but at the same time number of vehicles have increased exponentially. The vehicles are one of the major sources of NO_2. Measures taken to mitigate ambient NO_2 levels are introduction of improved vehicular technology in the form of Bharat Stage –III vehicles, banning of old vehicles in some cities, improved traffic management etc.

III. HARDWARE SYSTEM DESIGN

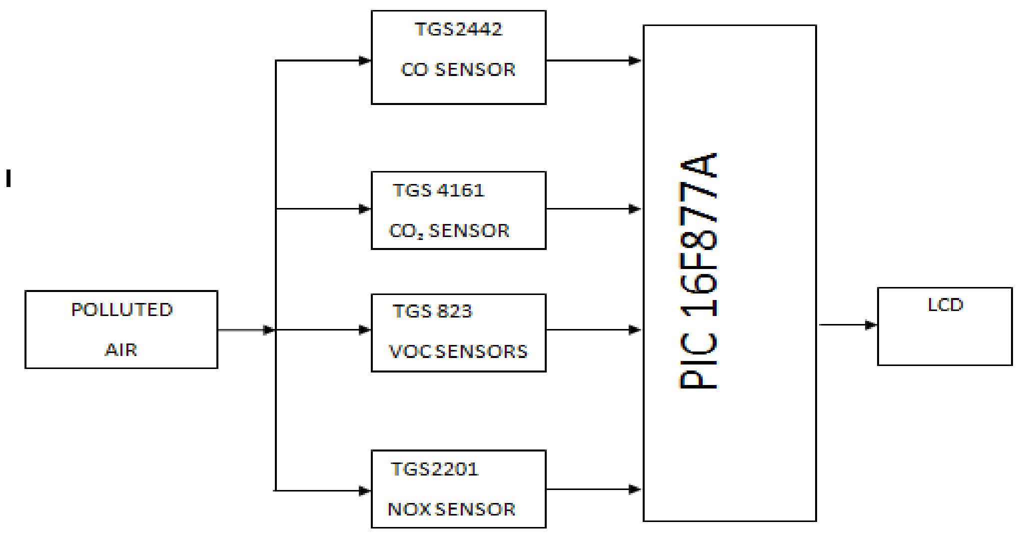

Fig. 2 Block Diagram of the Proposed System

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A. *Sensor Description*

The gas levels are sensed through the respective gas sensors (here TGS2442,TGS4161,TGS823,TGS2201) used for sensing and sent to the PIC 16F877A micro controller. The sensed analog signals are converted to digital through ADC (inbuilt in PIC). The sensed gas levels are displayed in the LCD.

- TGS2442 – CO sensor, response: resistance of SnO_2 layer on electrical insulation layer. Response time: tens of seconds;
- TGS4161 – CO_2 sensor, response: electromotive force which is the result of electrochemical reaction of CO_2 and electrodes made of gold and lithum carbonate with cation (Na^+) solid electrolyte. Response time: up to 1 minute, recovery time: up to 2.5minutes;
- TGS823 – VOC sensor. This sensor reacts to the presence of several volatile organic compounds, such as: Benzene (C_6H_6), Ethanol, n-Hexane, Acetone, Isobutane and others, but is used mostly for detection of Benzene which is found in highest concentrations. Response: resistance of SnO_2 layer, response time: tens of seconds;
- TGS2106 – NO_2 sensor, response: resistance of metal-oxide semiconductor layer. Response time: several seconds;
- TGS2201 – NO_x and CO sensor (double) used only for NO_x measurement, response: resistance of metal-oxide semiconductor layer. Response time: tens of seconds.

B. *PIC Microcontroller*

The Microcontroller used here is the PIC16F877A. It has attractive features and they are suitable for a wide range of application. It consists of I/O ports, 3 timers, ROM, RAM, Flash memory and inbuilt ADC. PIC channel 10 bit inbuilt ADC which convert the analog value into 10 bit digital data. PIC is programmed to convert 10 bit data into an 8 bit data and to transmit the data into a transistor driver. Microcontroller 16F877A has 40 pins, 32 pins for parallel port. One port includes 8 pins, so 32 pins formed 4 parallel ports; each of them is recognized as port 0, port 1, port 2 and port 3. Number of each pin of parallel port starts from 0 through 7, first pin of port 0 is named P0.0 and the last pin of port 3 is named P3.7.

1) *PIC Features*

• Only 35 single word instructions to learn.
• All single cycle instructions except for program Branches which are two cycle.
• Operating speed: 20MHz clock input, 200 ns instruction cycle.
• Up to 8k x 14 words of FLASH program memory, up to 368 x 8 bytes of Data memory
(RAM). Wide operating voltage range:2.0V to 5.5V

2) *Peripheral Features*
• Timer0: 8-bit timer/counter with 8-bit prescaler.
• Timer1: 16-bit timer/counter with prescaler,can be incremented during SLEEP mode.
• Timer2: 8-bit period register, prescaler and postscaler

3) *Analog Features*
• 10-bit, up to 8-channel Analog-to- Digital Convertor (A/D)
• Brownout Reset (BOR)
• Analog Comparator module with:
  - Two analog comparators.
  - Programmable on-chip voltage reference (VREF0 module.
  - Programmable input multiplexing from device inputs and internal voltage reference.
  - Comparator outputs are externally accessible.

4) *Micro Features*
• 100,000-erase/write cycle Enhanced Flash program memory typical.
• 1,000,000-erase/write cycle Data EEPROM memory typical.
• Data EEPROM retention > 40 years
• Self-re-Programming under software control
• In-circuit Serial Programming (ICP) via two pins
• Watchdog Timer (WDT0 with its own on-chip RC oscillator for reliable operation.
• Programmable code protection

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• Selectable saving sleep mode
• Selected oscillator options
• In-circuit Debug (ICD) via two pins

IV. IMPLEMENTATION

The various types of air pollutants like NO2, NOx, CO, and CO2 are sensed by the sensors TGS2442,TGS4161,TGS823,TGS2201 respectively and are monitored by the PIC microcontroller and displayed in the LCD. We take a sample polluted air for testing. This Polluted air is sensed by the sensors. The final ooutput is displayed in the LCD which will show the levels of each pollutant in the sample.

V. CONCLUSIONS

An efficient interface for monitoring air pollution has been implemented using gas sensors and PIC microcontroller. This system will show the levels of the air pollutant. By knowing these levels we study the possibility of reducing the pollution. We also planned for enhancing this study to cover river pollution with underwater sensors. Moreover the accumulation of waste in urban cities is planned for further studies.

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