Centralized Air Pollution Detection and Monitoring: A Review

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Abstract: ***Air pollution has become a major concern over the last quarter century and therefore mitigation of poor air quality for health and environmental reasons has been a primary focus for local governments. Industrialization and increasing number of vehicles are the primary source of pollution. There is ever rising need for continuous monitoring of air quality. A lot of technologies have introduced for measuring the air pollution. This paper presents a comparative study of the available technologies. Comparisons have been done based on measured pollutants, sensitivity, range, implementation cost, level of complexity etc., which are provided in tabular form for easy comparison. Paper also includes a proposed model which is an idea to implement the same as a real time project for air pollution detection and monitoring using microcontroller and Wi-Fi module.***

Keywords: Centralized Air pollution, particulate matter (PM), Sensor, Wi-Fi module, Arduino Microcontroller.

1. Introduction

In recent epoch, air pollution is an important problem in society that harms the human health and environment. This is a great problem faced in the urban area. Air pollution contributes to the greenhouse gases, which causes the greenhouse effects, whose side effects are well known to all of us. In recent time, there is a tremendous increase in pollution by the private vehicles. The main component of pollution from vehicles is oxide of carbon, which can be easily sense by the semiconductor gas sensors. These pollutants impact on the human health affecting lungs & respiratory system. These pollutants also deposit on soil plants, water etc. Various sensors can do the sensing of emitted gas. This paper suggests an idea, which is expected to help in reducing the pollution in air. Paper also includes a proposed model idea to implement the same as a real time project for air pollution detection and monitoring.

2. Literature Review

A literature study was done to compare the different methods for detecting and monitoring of air pollution, specially detecting toxic gases like CO, CH_4, particulate matter etc. The survey reveals various advantages and disadvantages of those methods. The methods are illustrates in the below section. In a factsheet by World Health Organization [1], WHO has mentioned that the air pollution is a major environmental risk to health, and by reducing the air pollution level one country can reduce the burden of heart diseases, lung cancer and both chronic and acute respiratory diseases including asthma. This factsheet suggests number of policies and investment supporting cleaner transport, cleaner municipal waste management etc. WHO's factsheet also presents a study of how much of the pollutant like SO_2, particulate matter (PM), NO_2 is acceptable in the air and their effects in the human health if they increase. The authors L. C. Amorim and J. P. Carneiro and Z. L. Cardeal [2] described Solid-phase microextraction (SPME) as a sampling technique for determining benzene in exhaled air by GC-MS. A system was developed to generate a gaseous benzene standard by a permeation method to accomplish the breath analyses. Authors also optimized the condition and analyses of real samples on two groups i.e., exposed and not exposed to benzene. Authors also mention that this method has good resolution, repeatability and sensitivity. In another literature, the authors Wei Ying Yi, Kin Ming Lo, Terrence Mak, Kwong Sak Leung, Yee Leung and Mei Ling Meng [8] have described the different technique of detecting the pollutant in the air and also explained the working of those techniques. The authors also performed a comparative study on the techniques based on their performance and cost effectiveness. The authors D. Hasenfratz and O. Saukh and S. Sturzenegger and L. Thiele [7] have described about the different

types of wireless nodes like community sensor node and static sensor node; and the author explained that community sensor node the sensor nodes are typically carried by the users. By utilizing the low-cost portable ambient sensors and the ubiquitous smart phones, users are able to acquire, analyze and share the local air pollution information. Similarly, in static sensor node the sensor nodes are typically mounted on the streetlight or traffic light poles, or walls. Due to the low-cost ambient sensors, the number of sensor nodes in SSN systems is much higher than that in the conventional monitoring systems. Again the authors P. Doraiswamy, W. T. Davis, T. L. Miller, J. S. Fu and Y. F. Lam [10] have performed experiments on trucks to detect its pollutant level. The authors used MQ-2 gas sensor along with an Arduino Uno board to detect the quality of the smoke produced by the exhaust pipe of the truck and after that they transmit the data through ESP8266 wireless transmitter to the predefined server and also design a mobile app to access the data. Similarly, in case of detecting the CH_4 in the air, the authors mentioned about the use of the sensor MQ-9 electrochemical sensor along with an Arduino Uno board.Authors F. Tsow, E. Forzani, A. Rai, R. Wang, R. Tsui, S. Mastroianni, C. Knobbe, A. J. Gandolfi and N. J. Tao [12] discussed about the MQTT protocol, in which the authors stated that it is a very low cost and low code footprint messaging system. Authors also established a connection between MQTT publisher and subscriber by using ESP8266 Wi-Fi module.

3. Different Pollution Monitoring methods existing

(i) Electrochemical Gas Sensing Method

The main principle of electrochemical gas sensing method is the electro chemical reaction specifically oxidation-reduction reactions in the sensor. An electrical signal proportional to the concentration of the gas molecule is generated by the reaction between the sensor and the gas molecules. This sensor is consist of three basic electrode these are Working Electrode (WE) and a Counter Electrode (CE) and Reference Electrode (RE) which is used to provide an external driving voltage. These three electrodes are separately deployed into the electrolyte within the sensor. For detecting and improving the selectivity to a specific kind of gas, different types of membranes, electrolyte and working electrodes are used. As soon as the gas reaches the working electrode, the oxidation-reduction reaction occurs. The electrode which is specifically developed for a specific gas catalyzes these reactions. By calculating the current between the Working Electrode (WE) and the Counter Electrode (CE) the concentration of the target gas is found. The Reference Electrode (RE) is responsible for controlling the oxidation and reduction reactions and reduces the potential drift on working electrode due to deterioration. It is to be noted that, most of the electrochemical ambient gas sensors require a small amount of oxygen and humidity to function properly. In addition, wind velocity also influences the chemical equilibrium on the sensor's surface and thereby influences the sensor's readings [7,8].

(ii) Tapered Element Oscillating Micro-Balance (TEOM) Method

In conventional air pollution monitoring system, this method is widely used. The main principle of this method is that oscillation frequency of the tapered glass tube is proportional to the mass of the tube. The mass and the oscillation frequency of the tube will be changed by the PM deposited onto the tube. By calculating the change in oscillation frequency of the tube and volume of the air sampled, researchers are able to deduce the mass concentration of PM in ambient air. The air is sampled through a size selective inlet [8].

(iii) β-Attenuation Method (BAM)

The β-Attenuation Method or β-Attenuation Monitors (BAM) are the most widely used particulate matter (PM) measurement equipment in the conventional air pollution monitoring systems. With the help of a size selective inlet (PM10 or PM2.5) the air is first sampled either with heater or without heater that minimizes the water contained in the air. After that air is passed through a paper filter which catches the PM and later on this paper filter is subjected to the β-attenuation source. By measuring the radiation intensity of the filter and the interval, one can calculate the mass of the PM on the filter [8].

(iv) Black Smoke Method

The black smoke technique collects the particulate matter (PM) on a paper filter over 24 hour period though a size selective inlet. A reflectometer is used to measure the darkness of the paper filter which is converted to the PM's mass concentration. This type of monitoring instrument is cost-efficent, simple and robust. After that, the mass concentration is obtained by measuring the darkness of the filter paper and this varies in different locations. This means the darkness-to-mass coefficient changes with time and locations. [8].

(v) Light Scatting Method

The main component of this method is a high energy laser which is used as a light source. Whenever a particle passes through the detection chamber that only allows single particle sampling, the laser light is scattered by the particle; and by using a photo detector, the scattering light is detected. By analyzing the intensity of the scatting light, one can deduce the size of the particle. Also, the number of particle counts can be found by counting the number of detecting light on the photo detector. A single analyzer can detect particles with different diameters simultaneously (i.e., PM2.5, PM5 and PM10), this is one of the advantage of this method. Once particle count is counted, it is converted to mass concentration by calculation (depends on the particle counts, particle types and particle shapes), but this will introduce errors that further affect the precision and accuracy of the analyzers which put a limitation to this method [8].

(vi) Direct Imaging Method

In this analyzer, the particle is illuminated with a beam of halogen light and the shadow generated due to the illumination of each particle is projected to a high definition, high magnification and high resolution camera. This camera records the passing particle and after that the video is analyzed by using computer software to measure the PM's attributes. By using this method both count and size of the PMs in the ambient air is obtained [8].

(vii) Light Obscuration Method (Nephelo meter method)

In this method, a particular category of optical analyzers uses the fastest particle concentration measurement method with high precision and low detection limited. A nephelo meter is an instrument that measures the size and mass concentration of PM in the ambient air. In a nephelo meter, one silicon detector and a near infrared LED are used. The LED is used as a light source and the silicon detector is used to measure the total light scatted by the particulate matter. Mass concentration and size distribution are determined by analyzing the intensities of light scattered by the PMs the shape of the scattering pattern. The TEOMs and BAMs are used in conventional monitoring systems due to their large size, heavy weight, high cost and high data resolution and accuracy. The light obstruction and the light scatting optical analyzer results have low resolution and accuracy and it varies with time and also with the location, yet these two type of sensor are widely used in hand-held monitoring devices and The Next Generation Air Pollution Monitoring Systems (TNGAPMS) due to their low cost, light weight, small size and simultaneously measuring ability [8].

(viii) WSN Based Air Pollution Monitoring Systems

In recent times, air pollution in the urban area has attracted extensive attention throughout the world due to its impact on human lives at anytime and anywhere. To mitigate these impacts, a network of monitoring stations using traditional measuring instrument have been deployed. Acquired data can be used to generate pollution maps and models, which can be used for predicting the environmental situation. Quality of service and limitation in spatio-temporal resolution plays a vital role in these systems. These limitations result in issues and problems of the conventional air pollution monitoring systems, like non-scalability of system, limited data availability on personal exposure, and out-of-the-fact warnings on acute exposure [8].

(ix) Static Sensor Network (SSN)

In SSN systems, the sensor nodes are typically mounted on the streetlight or traffic light poles, or walls. Due to the use of low cost sensor module in SSN system, the number of sensor in SSN system is much larger, in comparison to the conventional monitoring system. The pollution information that can be achieved with the SSN system has high spatio-temporal resolution. By the use of Webpages, Mobile app, etc., the air pollution data is available to the public [8].

(x) Community Sensor Network (CSN)

In CSN (or Participatory Sensing) systems, the sensor nodes are typically carried by the users. By utilizing the low-cost portable ambient sensors and the ubiquitous smart phones, one can acquire, analyze and share the local air pollution information. Air pollution data is available to the public through the Webpages, mobile app etc. [8,9].

Table 1 shows the comparison among various pollution monitoring methods.

Table 1: Comparison of different Pollution Monitoring methods

Method	Cost	Implementation	Sensitivity	Detectable Pollutant
Electrochemical Gas Sensing	Less	Easy to implement	Moderate	CO, CO_2, NO_2, CH_4, Propane, Butane etc.
Tapered Element Oscillating Micro-Balance (TEOM) Method	High	Equipment are large but it can be implemented	High	CO, CO_2, NO_2, CH_4, SO_2, etc.
β-Attenuation Method	High	Equipment are large but it can be Implemented	High	CO, CO_2, NO_2, CH_4, SO_2, etc.
Black Smoke Method	Cost-efficient	Simple to implement	Less	CO, CO_2, NO_2, CH_4, SO_2, etc.
Optical Method	Cost-efficient	Easy to implement	Moderate	CO, CO_2, Particulate Matter
WSN Based Air Pollution Monitoring Systems	Moderate	Simple to implement	Very High	--------
Static Sensor Network (SSN)	Low	Simple to implement	Very High	--------
Community Sensor Network (CSN)	Low	Simple to implement	Moderate	--------

4. Proposed model

The block diagram of a proposed model for Centralized Air Pollution Detection and Monitoring based on sensors, one microcontroller unit, and one Wi-Fi module, is shown below.

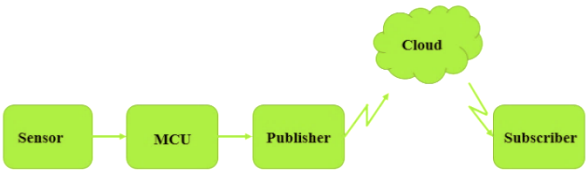

Figure 1: Block Diagram of proposed model

In this proposed model, a number of sensor nodes are being used and these sensor nodes will sense the various pollutants in the air. In the sensor node, the basic components are different types of sensors based on the requirement, one microcontroller unit, and one Wi-Fi module. The sensors are responsible for sensing the pollutant in the air and then it will generate some analog signal based on the concentration of pollutant in the air and this analog signal will feed to the analog pins of microcontroller unit and according to the incoming signal the board will process the signal and send it to the Wi-Fi module. The Wi-Fi module will publish the data to the cloud server. The cloud server is responsible for storing the sensor data and it also process the data to present in an interpretable way. The people who want to see those sensor data in the cloud server they can subscribe to the server and get those data. The Wi-Fi module is also used here to provide the location of the sensor, through geo-location. After getting those data and location of the sensor the server provides a complete scenario of the city pollution.

4.1 Components of the model

A brief working with specifications is given for the components that are used in the system.

(i) MQ2 Gas sensor

This sensor is simple to use which is used to sense the concentration of carbon monoxide in air. The MQ2 can detect CO gas in air between 20 to 2000ppm. This sensor gives quick response and is very sensitive to CO. The sensor gives output in analog form. To drive the sensor we have to apply 5V to the heater coil of sensor. This sensor has wide detection range; also it gives stable performance after it gets stable in the environment after some time. Its cost is low as compared to others. It is applicable for detecting domestic gas leakage, industrial co detection and portable gas detector. To calibrate this sensor we have to keep heating its heater coil for 48hours continuously. After this, the load resistance R_L needs to be adjusted until we get a single value, which is a response to a certain CO concentration and point of 90s. Then adjustment is required for the other load resistance R_L until we get a single value which responses to a CO concentration at the end point of 60s. After completing this task, the sensor is ready to use.

(ii) MQ4 gas sensor

This sensor is simple to use which is used to sense the concentration of methane gas (CH_4) in air. The

MQ4 can detect co gas in air between 200 to 10000ppm. This sensor gives quick response and is very sensitive to CH_4. The sensor gives output in analog form. To drive the sensor we have to apply 5V to the heater coil of sensor. This sensor has wide detection range; also, it gives stable performance after it gets stable in the environment after some time. Its cost is low as compared to others. It is applicable for detecting domestic gas leakage, industrial combustible gas detection, in car, etc. which uses methane as fuel and can be used in houses also. To calibrate this sensor we have to keep heating its heater coil for 48hours continuously. After this, the load resistance R_L needs to be adjusted until we get a single value, which is a response to a certain CH_4 concentration and point of 90s. Then adjustment is required for the other load resistance R_L until we get a single value which responses to a CH_4 concentration at the end point of 60s. Once this is over the sensor is ready for use.

(iii) Micro controller (Arduino Uno)

It is to be used for receiving data from the sensors and it stores one of the sensor values in the EEPROM. This receives analog value from the sensor and then it processes the analog value to convert it into parts per million. After converting this values both analog and ppm values will be displayed on the Liquid crystal display. The command will be given by the control to display these values on LCD.

(iv) Liquid Crystal Display (LCD)

This is the element that is used to display the concentration of gases present in the around atmosphere. This is a 16*2 display it has 16 characters to display in one line and it has total 2 line i.e. it can display total 32 characters. In this system, we have displayed the values of all the gases in analog and its corresponding value in ppm. At a time, the value of one gas is displayed in the first line analog value is displayed and in the second line concentration of gas is shown in ppm.

(v) Wi-Fi Module (ESP8266)

The ESP8266 module is a low-cost Wi-Fi microchip with full TCP/IP stack and microcontroller capability. It was introduced by Ai-Thinker in August 2014. This module establishes connection in between microcontroller and the Wi-Fi network by following TCP/IP connections.

4.2 Working Principle of proposed model

The working starts with the sensing of the sensor. In this system, there are two sensors that are MQ2 and MQ4. They sense carbon monoxide, methane respectively. They give analog output as per the concentration of gas present in the air produces analog signal at the output of sensor. This output is taken as analog input to the Arduino and then according to the programming, it processes the data and converts the analog value into its corresponding value in volts and parts per million (ppm). Equations given below are used to convert the analog value from the sensor.

(*i*) To convert analog to volts:

Volts = (5 × analog value from the sensor) / 1023

(*ii*) To convert analog value to ppm:

ppm = x × analog value

where"x" is the multiplying factor calculated as per the sensor by calibrating it in user's own environment.

After collecting the sensor data, the data is sent through the ESP8266 module by using MQTT protocol to the MQTT broker.

5. Conclusion

One of the major issues that we are facing today is Air pollution. Pollutions in earlier days were negligible. But nowadays pollution is increasing day by day because of so many reasons like industrial growth, development of automobile industries, chemical industries etc. So in order to reduce the pollutions from such type of sources and to protect the environment from toxic gasses, it is possible to take help of some of the semiconductor sensors such as MQ9, MQ7, etc. that helps in detection, monitoring, and also self-test of vehicles with the help of Microcontrollers.

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References

[1] "Ambient (Outdoor) Air Quality and Health", Factsheet, *World Health Organization*. [Online]. Available: http://www.who.int/mediacentre/factsheets/fs313/en/ [Accessed: 20 August 2017].

[2] L. C. A. Amorim, J. P. Carneiro and Z. L. Cardeal, "An optimized method for determination of benzene in exhaled air by gas chromatography-mass spectrometry using solid phase micro extraction as a sampling technique", *Journal of Chromatography B*, Vol. 865, Issues 1–2,

April 2008, pp. 141-146. Doi: https://doi.org/10.1016/j.jchromb.2008.02.023

[3] "Air Quality Health Index (AQHI)", *Environmental Protection Department, Govt. of Hong Kong*. [Online]. Available: http://www.aqhi.gov.hk/en.html [Accessed: 22 August 2017].

[4] "Beijing Environmental Statement 2013", *Beijing Municipal Environmental Protection Bureau*. Retrieved from: http://www.bjepb.gov.cn/bjepb/resource/cms/2014/06/2014061911140819230.pdf

[5] "Air", *Department of Environmental Conservation, New York State*, U.S.A. [Online]. Available: http://www.dec.ny.gov/chemical/281.html [Accessed: 22 August 2017].

[6] "Pollution Episodes", *London Air*, London Air Quality Network (LAQN): Monitoring Site, King's College London. [Online]. Available: http://www.londonair.org.uk/london/asp/PublicEpisodes.asp [Accessed: 22 August 2015].

[7] D. Hasenfratz, O. Saukh, S. Sturzenegger and L. Thiele, "Participatory Air Pollution Monitoring Using Smartphones", *Proceedings of 2nd International Workshop on Mobile Sensing*, April 16–20, 2012, Beijing, China. Retrieved from https://pdfs.semanticscholar.org/3f4f/00024beda5436dce4d677f27fe4209c3790f.pdf

[8] W. Y. Yi, K. M. Lo, T. Mak, K. S. Leung, Y. Leung and M. L. Meng, "A Survey of Wireless Sensor Network Based Air Pollution Monitoring Systems", *Sensors*, Volume 15, Issue No. 12, Dec. 2015, pp. 31392-31427. Doi: http://dx.doi.org/10.3390/s151229859

[9] W. Y. Chung and S. J. Oh, "Remote monitoring system with wireless sensors module for room environment", *Sensors and Actuators B: Chemical*, Vol. 113, Issue No. 1, January 2006, pp. 64-70.Doi:10.1016/j.snb.2005.02.023

[10] P. Doraiswamy, W. T. Davis, T. L. Miller, J. S. Fu and Y. F. Lam, "Measuring Air Pollution Inside And Outside of Diesel Truck Cabs", *Report Prepared for the U.S. Environmental Protection Agency by University of Tennessee*, Knoxville, November 4, 2005. Retrieved from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.401.6452&rep=rep1&type=pdf

[11] "SmartWay", *EPA, United States Environmental Protection Agency*. [Online]. Available: https://www.epa.gov/smartway

[12] F. Tsow, E. Forzani, A. Rai, R. Wang, R. Tsui, S. Mastroianni, C. Knobbe, A. J. Gandolfi and N. J. Tao, "A Wearable and Wireless Sensor System for Real-Time Monitoring of Toxic Environmental Volatile Organic Compounds", *IEEE Sensors Journal*, Vol. 9, Issue No. 12, Dec. 2009, pp. 1734-1740. Doi: 10.1109/JSEN.2009.2030747

[13] "How To - Build a Website", *w3schools.com*. [Online]. Available: https://www.w3schools.com/howto/howto_website.asp [Accessed: 23 Aug. 2017].

[14] S. Choi, N. Kim, H. Cha, and R. Ha, "Micro Sensor Node for Air Pollutant Monitoring: Hardware and Software Issues", *Sensors*, 2009, Vol. 9, Issue No. 10, pp. 7970-7987. Doi: https://doi.org/10.3390/s91007970

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