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Toxic gas detection using IOT Sensors: A Comprehensive study

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Abstract. Atmospheric pollution is the massive issue faced by the people worldwide. The primary sources of hazardous gases include ignition of coal, oil for electricity and transport, as well as emissions from industries and refineries. Volatile organic compounds are common in air pollutants which includes different kind of chemicals cause's adverse health effects. In last few years sensors which has high sensitive to VOCs had been used; this paper summarizes the latest advances in sensors for detection of pernicious gases. In addition analytical information revised here shows the efficacy of the existing approaches in toxic gas prediction and an improvement in terms of data validation techniques to improvise the accuracy.
Keywords: Volatile organic compounds (VOC), Data validation, Sensors, Air pollutants

1. Introduction

The increase in Earth's average surface temperature is mainly due to contamination in the air, this contamination originates from the combustion of fossil fuels such as coal, oil, and natural gases. Contaminated air can cause acute health challenges including carcinogenic, mutagenic problems [1]. The threat of toxic gases may cause suffocation and intoxication of the body. Death rate in chemical industries increases due to toxic gas leakage [3].

Gases like carbon monoxide are inodorous and colourless gas, these unseen gases generated by the burning of gases, fuels might cause life threats to human beings. Already India has seen such a disaster 'Bhopal gas tragedy', over 500,000 people were exposed due to the spread of gas leakage contains a toxic substance methyl isocyanate materials [20].

According to national safety council indoor air contains highest contaminated particles compared to outdoor air. Air pollution has huge impact on plant photosynthesis. Due to human fault and operation error toxic gas leakage accidents often put an end to many human lives. Exhalation of toxic gases can be easily traced and controlled by recent developments in Information technology such as sensor networks, and the internet of things. Air contamination is caused by major air pollutants summarized in Table1.

Table 1. MAJOR AIR POLLUTANTS AND ITS SOURCES

ATMOSPHERIC POLLUTANT	**SOURCES**
Carbon Monoxide	Combustion of disel,petrol,wood
Chlorofluorocarbons	Gases released from Refrigerator,AC

Nitrogen dioxide	Mainly from power plants burning oil gasoline etc.,
Sulphur dioxide	Production of electricity from gas, coal etc,.
Lead	Paint, Cosmetics, Medicines
Polycyclic aromatic hydrocarbons	Forest fire, Smog
Ammonia (NH3)	Fertilizers & textile industry,
Radon	Emitted by rocks and soil
Methane	Landfills and waste

Traditional methods such as thermal conductivity, infrared gas detector, and sensor-based detectors had been used so far for the detection of toxic gases.

The Survey of the paper is arranged as follows. Section 2 briefs about Prior work in toxic gas prediction and various types of IoT Sensors available for toxic gas detection. Discussions for validating data from different sensors are discussed in section 3. The Final section concludes with future work.

2. Related Works

Recent trends in the Internet of Things has introduced pocket sized, considerably low power sensors which can be easily integrated with electronic circuits for monitoring air quality system.
In order to detect toxic gases such as NO2, SO2, and H2S various types of electrochemical sensors are reviewed and summarized in[2].Author depicts that that hybrid materials based Sensors expose the highest proportion for NO2 gas sensing whereas SO2 and H2S are easily sensed by GaN and metal-oxide based sensors.

Using aluminium/iron oxides composites authors in [1] developed a Gaseous cataluminescence (CTL) sensor for harmful gas detection.

The authors in [4] used a series of sensors (MG811, MQ-7, 136, 4,131, and NOx to construct an automatic air pollution surveillance system. Arduino receives the data from multiple sensors compares the level of contamination with threshold value. If the contamination level crosses the threshold value, the system takes the contaminated gas which is connected to the neutralizers' storage unit. The storage unit neutralizes the toxic gas and releases its contamination.

Yufeng Fan et al. briefs about blueprint for a monitoring system which helps to avoid accidents during fire suppression. Thus it creates an efficient monitoring terminal that can launch the hazard model for monitoring area of pernicious gas. Based on the proposed model design it could design the data set structure and network structure of various neural network model, it was easy to identify the early warning of toxic and harmful gases on locations. The proposed model uses the RNN model structure for building a gas monitoring system.[7]

Jun Ho Jo et al. proposed a prototype for an indoor air quality inspection system. Different types of sensors are deployed to collect the data for air quality analysis. Collected data is sent to the web server through LTE module and further analysis with visualization is made. [9]

Chang Jun Hou et al., discusses about a cost efficient gas detection device using a battery operating mechanism. Cross responsive sensors are used to detect toxic gases. The Authors used the image processing technique to extract the gas characteristics individually. Five different types of toxic gases were analyzed in this paper. FLUENT software is used to optimize the gas chamber model. The developed model is a high speed, inexpensive device and it is used to monitor various types of toxic gases in an efficient way. [6]

Ramya et al. published an interesting prototype of a monitoring device in a vehicular cabin to identify the carbon monoxide and oxygen gas. This paper explains the security of a vehicle while toxic gases released. It shows that the alarm techniques are used when carbon monoxide is released above the threshold level and proximately ventilation provision has been given. Similarly oxygen level also checked if it is less than the threshold level, proper action has been handled by the device. [5]

Dami Kim et al. designed a Smartphone application to detect toxic gases. Array reader concept is used for communication with smart phones. In this research array readers were used to identify the changes of colour using CMOS image sensors during leakage of hazardous gases. In this paper, the following types of gases named Ammonia, methylamine and trimethylamine gas were used to evaluate the performance of array readers. It was observed that toxic gases were identified using array reader via Smartphone it could also be used in social network services or in control rooms. [13]

In paper [8] authors summarize about different kind of gas sensors that are of foremost importance. Pattern recognition and sensor arrays play a vital role in real-time toxic gas sensing which can able to warn about material going to start burning.

2.1. IOT enabled Gas sensors

The definite type of gases that has to be detected depends on the feed materials used by the industries, there are IOT based sensors that detect the multiple gases as well. These types of sensors are normally battery-powered and transfer cautions when a dangerous level of toxic gases is detected. Overall the type of sensor detection techniques for toxic gases is briefed below

2.1.1 Electrochemical sensors

Toxic gas scattered from various sources reaches the working electrode causes an electrochemical reaction. Due to oxidation electron conductors are moved to counter electrodes through electronic circuits. Toxic gas interacts with electrolyte produces a current related to concentration [10].EC Sensors are real time, Easy and faster detection of a wide range of toxic gases compared to conventional methods. These types of sensors are affected by obstruction from other gases and environmental factors

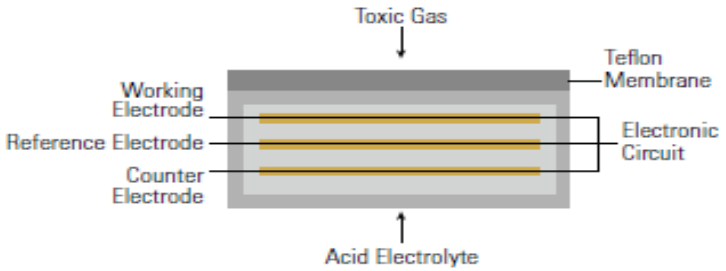

Figure 1. Working model of Electro chemical sensors

2.1.2 MQ sensors

MQ is series of low cost, safe sensors used to detect various kinds of toxic gases includes LPG, aerosols, carbon monoxide, propane, hydrogen, methane, etc. It is a metal oxide semiconductor measures the concentration of gas using voltage divider network.MQ sensors are highly sensitive to toxic gases. Different series of MQ sensors are used for identifying varieties of gases is a major weakness. [11]

Figure 2. Structure of MQ sensors

2.1.3 Catalytic Sensors

Combustible gases can be easily detected with catalytic sensors. It contains a catalytic substance sensitive to combustible gases. Combustible gases blaze on detector induces an increase in temperature. It is low cost, and low obstruction from other gases compared to conventional sensor methods. The major weakness of using catalytic sensors is oxygen is needed to perform gas detection [12].

2.1.4 Acoustic sensors

This type of sensor reacts to escaping toxic gases at ultrasound frequency. At elevated pressure, toxic gases produce ultrasound up to 100 kHz which can be detected by this kind of sensors. Unlike traditional methods, Acoustic types of sensors detect a mixture of gases. It is difficult to use this type of sensors in the fabrication process due to its miniature size.

2.1.5 Infrared sensors

IR sensors are commonly used to detect hydrocarbon, carbon monoxide and carbon dioxide gases. Toxic gas detection is based on the uptake of Infrared radiation at certain wavelengths.IR has several advantages includes low maintenance, high fidelity, and low maintenance. A substantial amount of gas is required in this type of sensor to detect toxic concentration.

3. Discussion and Open Issues

In previous sections, different types of sensors with gas sensing technologies for IoT based applications are discussed. This section briefs about solutions for data validation techniques if multiple sensors were used. Sensors are sensitive to faults. A fault has the ability to cause operation failure or even to put the system and its surroundings in risk. In order to obtain reliable results, data validation and verification are necessary to validate the data from multiple gas sensors. Validating data plays a vital role in critical systems like gas sensor prediction. Available data detection and correction methods are consolidated in [14].

According to [16] in the process of machine operation, most of the industries face the bearing failure issue. Earlier detection of this kind of failure can stop the shutdown of production due to bearing fault. Multiple sensors deployed on bearing base are used to diagnose the fault. This paper proposed a model using a Deep belief network (DBN) a kind of Deep neural network. Results show that DBN has higher accuracy than traditional methods in finding the fault.

Systems fitted out with low performance microprocessors are not suitable for using advanced techniques such as neural networks, fuzzy for identifying sensor fault. Authors of the paper [17] used statistical measures such as Root mean square (RMS), variance and kurtosis to identify the sensor fault detection in unmanned aerial vehicles.

Nowadays Heat ventilation and air conditioning systems (HVAC) are equipped with sensors for automatic building monitoring systems. Sensor fault in such an air handling unit is diagnosed by principal component analysis method. Authors in [18] concluded that the Q-statistic method in PCA is used to identify fault detection and diagnosis.

Han et.al applied Fault detection method to automatic chillers unit leads to least cost maintenance and lesser downtimes. Genetic algorithm based FDD method was used.
Authors in [20] simulated a HVAC system in TRANSYS and proposed an Auto associative neural network model for sensor fault diagnosis.

During the process of toxic gas detection, various types of sensors are deployed in different environments; it is very difficult to validate the results of sensors.

For reliable air quality monitoring, it is necessary to have accurate sensor information. Various techniques applied for fault diagnosis and validation of air quality monitoring networks are charted below. [15]
Major categories of sensor fault detection methods are summarized in Figure 3.

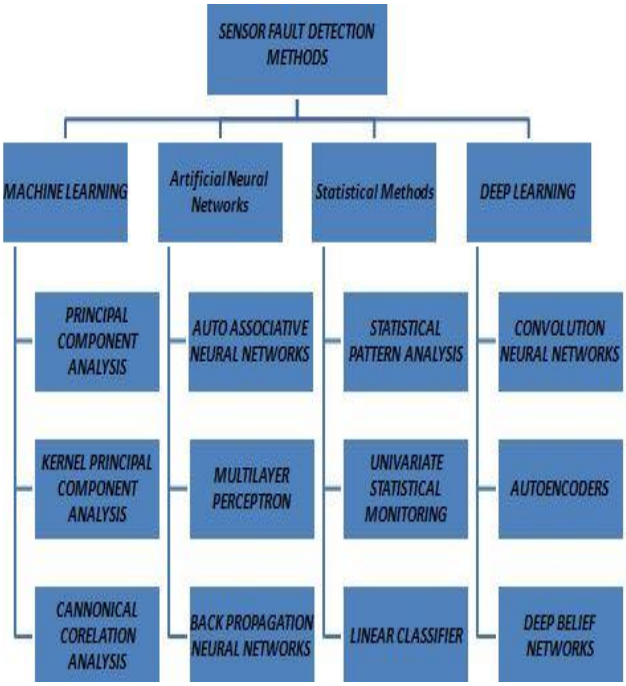

Figure 3. Chart for Sensor fault detection Methods

4. Conclusion

Air quality surveillance system needs to be strengthened in all over the world; toxic gases released from various sources pose a certain threat to the environment, as well as affect people's general state of health. This paper reviews the various gas sensing technologies and prototypes proposed by different authors. The different IoT related gas sensors are detailed including its properties with benefits and drawbacks. Faulty detection and validation methods are revised to handle the sensor malfunction. In future

appropriate data validation technique can be incorporated for optimized sensor output in toxic gas detection.

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