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Air Watch: An Ample Design of Indoor Air Quality Monitoring System

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Abstract— The environment is getting contaminated drastically by introducing harmful materials into the atmosphere through the excessive activities of human in adding comfort and luxurious style in their living. The pollutant level in air has high impact of healthiness of the person inhaling it. Air not outside as well indoor is infected by various hazardous particles and gases. To assess the air quality in the particular environment, it stimulates the need to monitor the hazardous elements listed. The internet of things (IoT) and artificial intelligence (AI) became the part of human life by adding smartness in their daily routines from facilitating control over appliances to own health factor as well automate operations. The primary objective of the effort is to identify the gases that cause air pollution, measure the air quality, and assess the level of pollution so that we can determine which gases cause pollution and at what place is the air being impacted. An IoT based indoor air quality monitoring system is built through incorporating carbon monoxide (CO), carbon dioxide (CO2), Ozone (O3), particulate matters (PM) and volatile organic components (VOC) sensors into Arduino board. The design ensures a complete air monitor, extends reliable service at low cost. A rule based system is developed to automate events upon the estimated air quality index (AQI) out of the sensory circuit.

Keywords- air quality index; artificial intelligence; environment pollution; internet of things; rule based system; wireless sensorsr.

I. INTRODUCTION

Our living environment has an impact on our quality of life. In general, the environment is made up of both living and non-living things that work together to ensure its survival. The three basic necessities for human survival are air, food, and water. The excessive human actions to enhance comfort and affluent life are severely contaminating the environment by releasing toxic substances into the atmosphere. The amount of pollution in the air has a significant impact on the health of those who breathe it in [1-3].

In generic terms, air pollution is the presence of toxic elements in air causing environment degradation and significantly affects the health factor of living things. Due to industrialization, increased vehicles and contemporary cooking practices in rural area emit hazardous gases into the air and that induces the pollution [4]. A statistical report by Health Effects Institute on 2018 revealed a fact that 1.1 million deaths caused in 2015 due to the air pollution. Further worldwide survey of 2019, India positioned fifth place in air pollution victims. It is also determined that around 21 major cities in India are highly polluted. In 2020, indoor air pollution was determined to be the cause of 3.2 million annual deaths, including approximately 237000 lives of kids lesser than 5 years [5].

An extensive internet study revealed that there is a definite yearly increase in demand for air quality monitoring. Because to its industrialization practices, the Asia-Pacific area in particular consistently exhibits high levels of pollution, with China, India, and Japan holding the top three spots on the list of the most polluting nations. The survey also showed that the Bombay Municipal Corporation (BMC) is creating a network for monitoring air quality across many Mumbai areas, and that network is anticipated to be finished by 2025.

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Simple instruments called air quality monitors are used to record the quantities of atmospheric pollutants in a certain area. It comes in indoor and outdoor varieties. Indoor monitors are used to function inside the designated area, such as a house, hospital, or other building. The outdoor monitors are set up outside to calculate the effects of environmental contaminants over time. The air indoors is two to five times more harmful than the air outside, according to an environment pollution board (EPA) analysis. As a result, the indoor units of air quality monitors receive greater focus than the outdoor ones.

The rest of the article is structured as follows: the significant past efforts made by researchers are captured in section 2. The section 3 details the IoT design and machine learning algorithm applied. In section 4, the attained results and the way to realize as application are discussed. The section 5 tends to conclude the work along with its futuristic scope.

II. LITERATURE REVIEW

This section goes into detail on the outstanding contributions made by several researchers in finding solutions for indoor air pollution monitors.

A. Related Work

B. C. Singer et al. [6] analyzed the level adaptation of indoor air quality monitors regularly. In this work, the commercial and research grade quality monitors were identified and its features also keenly elaborated. Marco Gola et al. [7] reviewed the chemical components of inpatient ward and its impact over the patients in observing those pollutants.

Gonçalo Marques et al. [8] conducted a survey on air quality monitoring system, its existing forms and challenges to rule out. It was noted that 70% of air quality monitors used CO2 and PM as its major element in assessing AQI. While coming to IoT enabled solutions, it was revealed that Arduino and raspberry pi are the prime boards of implementation. It envisioned that energy efficiency is to be incorporated for better operation of air quality monitors.

James Heydon et al. [9] carried out a comprehensive study over the role of portable air monitors in protecting children from pollutants. The regular monitoring of the environment for pollutants facilitates the children in safer place and migrate them upon forecasted emergency circumstances. Jagriti Saini et al. [10] deeply investigated indoor air pollution (IAP) and listed the major pollutants of IAP. He also presented the significance of wireless sensor network and IoT in providing real time monitoring support for this. He also revealed a few noteworthy contributions of the researchers in this domain. The appropriate wireless sensors to be used with air quality monitoring are highly discussed [11].

Devahema et al. [12] developed an air pollution tracking system using IoT. The level of most hazardous gases like Alcohol, benzene, CO2, NH3 and smoke in the air was determined with the help of MQ135 sensor. The mobile application designed for this system enabled the person to operate anywhere, visualize the pattern anytime and signify an alert upon relevant circumstances. Harsh N. Shahet al. [13] designed an IoT based air monitoring device that assesses the air quality in the environment and attempts to calculate the presence of harmful gases such as benzene, CO2 and NH3 through obtaining the air quality index as parts per million (PPM). This method used MQ6 sensor to capture liquid petroleum contribution while estimating others using MQ135. Likewise for indoor air monitoring, IoT is renowned as a major platform for implementation [14-19].Soto-Cordova et al. [20] designed an IoT based air quality monitor to observe the PM levels around the surroundings. Aimed to obtain a low cost module, real time computation practiced in cloud, operated through message queuing transfer and telemetry (MQTT). The Adafruit boards were used to enable visualization support for the application. Similar attempt to predict CO2 concentration using IoT is found in [21]. Jun Ho Jo et al. [22] delivered an air quality monitoring system named “Smart-Air” incorporating technologies like IoT and cloud computing. The same is tested and evaluated under the norms of Ministry of Environment, Korea.

Ajitesh Kumar et al. [23] devised a real time air monitoring solution kit using IoT. This system attempted to monitor air quality by observing the presence of the CO, PM and others in the environment. Also the system is designed to analyze the obtained data and alert the neighborhood using a buzzer. The IoT based air quality monitoring is developed with modern sensors [24, 25] and secure integration with cloud is elaborated [26]. In order to assess environment air quality index, the usage of fuzzy logic is well demonstrated [27].

Shaharil Mad Saad et al. [28] exercised the application of machine learning algorithms in detecting air pollutants. Chris C. Lim et al. [29] Proposed a machine learning approach to boost the performance of low cost sensors at the edge device and bring optimal solution. The proposed approach collaboratively used linear regression, random forest with ensemble learning to provide best possible results.

B. Air Quality Monitors in Real

Prana Air is a web portal owned by Purelogic Labs Pvt. Ltd., India, provided services in promoting air products like filters, masks, monitors and purifiers designed for indoor as well outdoor. The remarkable products of Prana Air are as follows:

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- CAIR Monitor - portable and real time solution, measures the atmospheric temperature, humidity, PM2.5, PM10 and pressure. Costs as ₹6500
- Sensible Monitor – evaluates AQI by calculating PM1, PM2.5, PM10, CO, CO2, O3, HCHO, TVOC, Temperature & Humidity as its major toxic elements and costs around ₹35000
- Squair Monitor – estimates the AQI by assessing the hazardous elements such PM1, PM2.5, PM10, CO, CO2, O3, HCHO, TVOC, Noise, Light, Temperature & Humidity all into the consideration. Forecasts the AQI by inherent analysis triggered between real time and historical values. The cost of the monitor is ₹60,000

AQI India is also launched by Purelogic Labs Pvt. Ltd., India promotes Prana Air products, estimates and presents the AQI various parts of India in its dashboard design. It uses Prana Air monitors to obtain the value of toxic elements in air, integrating the same with weather report forecasts the same.

C. Research Objectives

The previous attempts in designing an air quality monitor use only few toxic gases into an account. The complete air quality analyzer working on wide spread of pollutants in air is complex to design and in turn imposes high cost. The proposed model is to make an attempt to bring complete air quality monitor with the following features:

- Accurate in predictions
- Portable in size
- Provide reliable service all the time
- Easy to use
- Low in cost

III. Proposed System

The work utilizes the modern technologies like artificial intelligence, cloud computing and IoT to enable an indoor air quality system. It will keep track of pollution control around the environment being installed and initiate the necessary action.

A. Air Pollutants

Numerous air pollutants, such as NO2, SO2, O3, CO, volatile and semi-volatile organic compounds (VOCs), PM, radon, and microorganisms, have been identified as being present indoors. The presence of certain of these pollutants (such as NO2, SO2, O3, and PM) is frequent in both indoor and outdoor settings, and some of them may have their origins outside.

TABLE I. Indoor air pollutants with health impact

Major Pollutants	Health Effect
CO2	Headaches, tiredness, high blood pressure, aggravated heart rate, difficulty in breathing, sweating
CO	Confusion, dizziness, fatigue, headaches
NO2	Respiratory infections, asthma to chronic lung diseases
O3	Cataract, skin cancer, impaired immune system
PM 2.5	Irritation on eye, nose and throat, coughing, runny nose, shortness to breath
VOC	Headaches, nausea, irritation, liver & kidney damage
Temperature	Sweating, headache, fatigue, light headedness, rapid breathing, rapid heartbeat, and heated discomfort

These air pollutants can have different effects on different people depending on their toxicity, concentration, and exposure period. The most prevalent impact is known as sick building syndrome (SBS), in which people have uneasy or acute health symptoms like nose, eye, and throat irritation, skin conditions, allergies, and other conditions. The syndrome might not have a known origin, but it might disappear if a victim leaves the workplace or structure. Upon deep investigation, the principal air pollutants that are directly associated with a high risk to human health are identified, grouped as four interior air pollutants (IAP) namely CO, CO2, NO2 & O3 and four thermal comfort pollutants like PM2.5, VOC, temperature & humidity which is summarized in Table 1.

B. Air Watch: An Indoor Air Quality Monitor

In order to build a complete air quality monitor, the significant pollutants listed in Table 1 are accounted in the design. A 2.8" Nextion touch display and an Arduino Pro Mini board work together to create a functional user interface for this work. One can view all of the sensor measures in real time through a single click on a specific sensor. The device is composed of five main air sensors as follows.

PM2.5, or airborne particulate matter, is measured with a PMS5003 sensor and has a diameter of around 2.5 microns. The laser scattering theory underlies the operation of this sensor. The sensor contains a fan that generates a controlled airflow that allows ambient particles to pass through a laser beam that is tightly focused. The photodiode detects the light diffraction caused by the particulates and uses its microcontroller to transform it into the PM concentration. This sensor's output, which includes PM1 and PM10 measurements in addition to PM2.5, has been shown to be quite trustworthy.

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The CO2 is measured using MH-Z19 sensor. The sensor measures the amount of CO2 in the air using a non-dispersive infrared approach. While allowing certain wavelengths to get through, the CO2 gas molecules in the atmosphere which we track absorb a particular band of IR light. Therefore, the variance between the sum of the amount of light that is emitted and the amount of IR light that is received by the detector is used to determine the CO2 level.

The proposed system utilized MQ135, MP503, and the MQ131 gas sensors to measure CO, VOCs, and ozone. These heated metal oxide sensors work by monitoring changes in resistance in response to the presence of specific gases.

The DHT22 is frequently used to measure temperature between -40°C and 80°C and humidity within 0% to 100%. Furthermore it is factory calibrated, hence it can be integrated with other microcontrollers easily. The proposed air quality monitor named as ‘Air Watch’ is captured in Figure 1. The serial communication is established to transfer data between sensors, development board and the display unit with serial ports. The Figure 2 is intended to present the same.

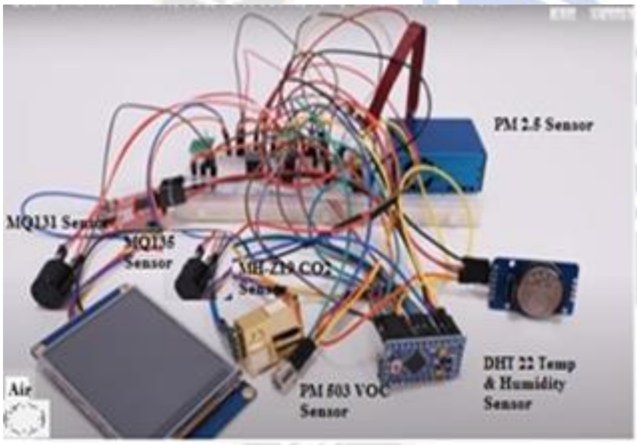

Figure 1. The proposed air quality monitor.

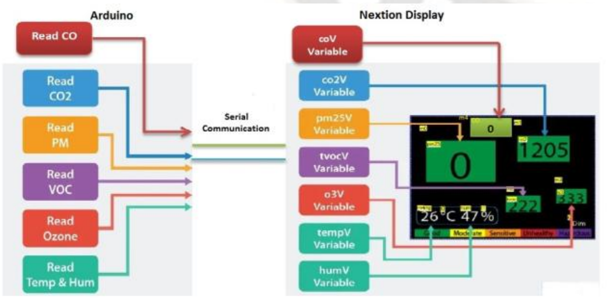

Figure 2. Schematic of data communication in the proposed air monitor.

C. *Air Quality Classifier: Rule based Reasoning*

The three main categories of reasoning approaches are statistical, computational intelligence, and knowledge driven (Mshali 2017). The rule-based reasoning in the knowledge-driven approach is put to use by using the observed computational complexity. The method tries to make a thorough observation of the user's context in relation to the posed situations while determining the air quality. Furthermore, this knowledge creates the formal logics needed to determine an air quality status. The knowledge developed through deeply inferring the parameters has a significant impact on the prediction's accuracy. The rules are created by determining values that can be deduced from parameters using examples like the ones below.

R1: if (AQI. value = 20 and room temperature. value = 29 and noise level. value = 30) then Signify "Environment is good"

R2: if (AQI. value = 410 and room temperature. value = 60 and noise level. value = 110) then Signify "Environment is polluted severely"

IV. RESULTS AND DISCUSSIONS

In general, the association between indoor and outdoor pollution level is obtained by the equation 1 below.

$$I/O = \frac{Cin}{Cout} \qquad (1)$$

Where Cin is the pollutant concentration of the indoor air and Cout is the pollutant concentration of the outside air. The I/O ratio >> 1 specifies there exists dominant indoor source, if the I/O ratio == 1 notifies the equal contribution of both the indoor and outdoor sources, for the case I/O ratio << 1 signifies the presence of the dominant outdoor source. By considering various factors such as penetration index (P), air exchange rate (a), volume of the building / house (V), decay rate of sedimentation (k) and the mass flux created (Qis), the mathematical expression used to obtain indoor concentration is captured as equation 2.

$$Cin = \frac{PaCout + \frac{Q_{is}}{V}}{a + k} \qquad (2)$$

The air exchange rate (AER) specifies the amount of influences of outdoor air brought into the inside air and it is denoted as equation 3 as follows.

$$AER = \frac{1}{t}\ln\frac{C_r}{C_o} \qquad (3)$$

The concentration of inside air is redefined as equation 4 by considering the multiple sources of interest.

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$$Cin = \frac{P\,a\,Cout + V^{-1}\sum_{i=1}^{n} Q_{is}^{i}}{a+k} \qquad (4)$$

Finally, the formula to obtain the air quality index is specified as equation 5 as below.

$$AQI = \frac{AQI_{Hi} - AQI_{Lo}}{Conc_{Hi} - Conc_{Lo}} \times \left(Conc_i - Conc_{Lo}\right) + AQI_{Lo} \qquad (5)$$

In the expression Conci corresponds to input concentration of the pollutant. Whereas ConcLo is concentration breakpoint less than or equal to Conci and ConcHi is concentration breakpoint greater than or equal to Conci. Further AQI_{Hi} and AQI_{Lo} are AQI value corresponds to $Conc_i$. The AQI mapping of hazardous supplements in the air, its acquired level and the risk factor is clearly provided as Table2.

TABLE II. AQI OF INDOOR AIR POLLUTANTS

Daily AQI Color	Levels of Concern	Values of Index	Description of Air Quality
Green	Good	0 to 50	Air quality is satisfactory, and air pollution poses little or no risk.
Yellow	Moderate	51 to 100	Air quality is acceptable. However, there may be a risk for some people, particularly those who are unusually sensitive to air pollution.
Orange	Unhealthy for Sensitive Groups	101 to 150	Members of sensitive groups may experience health effects. The general public is less likely to be affected.
Red	Unhealthy	151 to 200	Some members of the general public may experience health effects; members of sensitive groups may experience more serious health effects.
Purple	Very Unhealthy	201 to 300	Health alert: The risk of health effects is increased for everyone.
Maroon	Hazardous	301 and higher	Health warning of emergency conditions: everyone is more likely to be affected.

The reading (hazardous air particles) out of air monitor is processed via cloud application programming interface (API) known as Thingspeak and the same is presented as Figure 3 along with AQI estimation.

Figure 3. Visualization of air quality through Thingspeak.

Assembling, visualizing, and analyzing real-time data streams in the cloud is possible with the help of the IoT analytics platform service ThingSpeak. Data sent by your devices to Thing Speak is instantly visualized by ThingSpeak. You can process and analyze data online as it comes in because of ThingSpeak's ability to run MATLAB code. IoT solutions that require analytics are frequently prototyped and proof of concept using ThingSpeak.

V. CONCLUSION

The essence of air quality monitoring, the hazardous substances of indoor environment and its impact is deeply investigated. A complete design of cost effective air quality monitor along with AQI calculation is presented. Upon thorough analysis, the appropriate sensors for air quality monitor are identified. The well integration of the selected sensors on the Arduino board provided the air monitor. After calculating AQI, the status of the environment is indicated through the user by employing simple rule based approach. In future to enhance the accuracy of prediction, machine learning algorithms can be utilized.

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AUTHORS CONTRIBUTION

All authors contributed equal to this work.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest regarding the publication of this paper.

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