IoT (Internet of Things) has become an integral part of our lives and it has already made an impact in various sectors, including the environment. Air pollution is a severe problem that has been affecting our planet for years. Therefore, there is a need for a reliable and efficient air pollution monitoring system to protect ourselves from its hazardous effects. An IoT-based air pollution monitoring system is an ideal solution that can provide real-time data and insights about the air quality in a particular area.

An IoT based air pollution monitoring system consists of several hardware and software components that work together to collect and process data. The hardware components include sensors, microcontrollers, and communication modules. The software components consist of a cloud platform, a mobile application, and a web-based dashboard.

The IoT-based air pollution monitoring system provides several benefits over traditional air pollution monitoring systems. It can collect real-time data from multiple locations, which then analyzed to identify the sources of pollution. It helps to take necessary measures to reduce it.

The system can also alert the users if the air quality reaches a dangerous level, allowing them to take precautions to protect themselves.

Monitor Air Quality: The primary purpose is to continuously monitor and measure various air pollutants, such as particulate matter (PM), nitrogen dioxide (NO2), ozone (O3), sulfur dioxide (SO2), carbon monoxide (CO), and volatile organic compounds (VOCs) in the ambient air.

Real-time Data Collection: The system aims to collect real-time data on air quality, enabling immediate awareness of pollution levels and trends.

Early Warning System: By detecting changes in air quality, the system can serve as an early warning system for potential health hazards and environmental risks.

Environmental Protection: The system supports efforts to protect the environment by identifying pollution sources and evaluating the impact of emissions on air quality.

Public Health Improvement: By providing accurate and up-to-date air quality information, the system helps individuals and authorities take measures to protect public health, especially for vulnerable groups like children, elderly, and individuals with respiratory conditions.

Compliance Monitoring: The system aids in ensuring compliance with air quality regulations and standards set by local, regional, and national authorities.

Data Analytics and Insights: Collected data can be analyzed to gain insights into air pollution patterns, contributing factors, and long-term trends.

Decision-making Support: The system provides valuable data to support informed decision-making by governments, businesses, and individuals in areas like urban planning, industrial operations, and personal activities.

IoT Integration: The use of IoT technology allows for seamless data transmission, remote monitoring, and system scalability.

Environmental Research: Data collected from these systems can support environmental research and studies on air pollution, climate change, and public health.

**IoT Monitoring System components**

IoT-based air pollution monitoring systems comprise several components that work together to collect and analyze air quality data. The components include:

Sensors: Sensors are the primary components of IoT-based air pollution monitoring systems. They measure various air quality parameters such as particulate matter, carbon monoxide, sulfur dioxide, and nitrogen oxides. The sensors can be classified into two categories: physical and chemical sensors. Physical sensors measure parameters such as temperature, humidity, and pressure, while chemical sensors measure air pollutants.

Microcontroller: The microcontroller is the brain of IoT-based air pollution monitoring systems. It receives data from the sensors, processes it, and sends it to the cloud server. The microcontroller is usually a microprocessor such as Arduino, Raspberry Pi, or similar devices.

Communication Module: The communication module is responsible for transmitting data from the microcontroller to the cloud server. Communication modules can use various wireless technologies such as Wi-Fi, Bluetooth, or cellular networks.

Cloud Server: The cloud server is a centralized platform for storing, analyzing, and sharing air quality data. It collects data from the communication module and stores it in a database. The cloud server also provides web and mobile applications for users to access the data.

Power Supply: IoT-based air pollution monitoring systems require a power supply to operate. In case of permanent installations external power supply is provided and batteries are provided for portable devices.

Enclosure: The enclosure is the outer covering that protects the components from environmental factors such as dust, water, and temperature.

In Short, the sensors measure air quality parameters, the microcontroller processes the data, the communication module sends the data to the cloud server, the cloud server stores and analyzes the data, and the power supply and enclosure provide power and protection to the system. By working together, these components enable the development of accurate and reliable air pollution monitoring systems.

Usage of Monitoring System

The IoT-based air pollution monitoring system can be used in various settings, including residential, industrial, and urban areas. It can also be integrated with existing air pollution monitoring systems to enhance their capabilities. The system can provide valuable data to government agencies, researchers, and the public to make informed decisions about air pollution.

One of the significant advantages of an IoT-based air pollution monitoring system is its scalability. The system can be easily scaled up or down based on the needs of the users. It can be customized to meet the specific requirements of a particular location, making it a versatile solution for air pollution monitoring.

An IoT-based air pollution monitoring system is a revolutionary solution that can provide accurate and real-time data about the air quality in a particular area. It can help identify the sources of pollution and take necessary measures to reduce it, protecting the environment and human health.

With its scalability and versatility, the IoT-based air pollution monitoring system can be used in various settings and integrated with existing air pollution monitoring systems, making it an ideal solution for air pollution monitoring.

While air is definitely essential to sustain life, its influence on industries is far greater. The quality of air determines the performance of workers which further influences the productivity and efficiency of the entire plant.

Air also affects the operational costs of a company. Corrosive particles and gases present in the atmosphere can act as a catalyst for rusting and decomposition of the metal body of various industrial equipment, resulting in more repair and maintenance expenses. Furthermore, the presence of air or increased concentration of a particular gas in the air can affect the manufacturing processes, resulting in reduced quality of manufactured goods.

Quality of air hence plays a major role in determining the overall performance of an industry. Especially in industries like mining, oil and gas, chemical, etc.; which deals with harmful gases or are subjected to aerosols; the air quality monitoring systems are a must.

Using IoT as an Air Quality Monitor:

IoT as an interconnective device acts as a perfect medium to determine the quality of air in a particular facility. High-end devices like sensors and meters embedded in strategic places can be used to ascertain the air quality index (AQI) or identify the presence of a particular harmful gas.

Powered with features such as real-time monitoring, multi-channel alerts, and advanced analytics; IoT systems are the best tools to monitor air quality. The data is transmitted to a centralized platform without any latency that enables the monitoring of AQI of a location from anyplace.

An IoT-based air quality monitoring system has numerous applications across various domains. Some examples:

1. Environmental Monitoring: IoT-based air quality monitoring systems can be deployed in cities, industrial areas, and residential areas to continuously monitor air pollution levels. This data can help identify pollution sources, track pollutant trends, and assess the effectiveness of pollution control measures.
2. Health and Safety: These systems can be used in hospitals, schools, and workplaces to monitor indoor air quality and ensure a healthy environment. They can detect harmful gases, volatile organic compounds (VOCs), and particulate matter, providing early warnings and allowing prompt action to be taken to protect people's health.
3. Smart Homes: IoT devices can be integrated into home automation systems to monitor indoor air quality and automatically control ventilation, air purifiers, and HVAC systems. This helps maintain a healthy and comfortable living environment.
4. Industrial Applications: IoT-based air quality monitoring systems are valuable in industrial settings to monitor emissions, chemical leaks, and workplace air quality. Real-time data can be used to optimize industrial processes, ensure compliance with environmental regulations, and protect the health of workers.
5. Urban Planning: City planners can utilize air quality data collected from IoT devices to make informed decisions regarding urban development, transportation infrastructure, and zoning. This helps in designing cities that prioritize environmental sustainability and public health.
6. Traffic Management: IoT-based air quality monitoring systems can be integrated with traffic management systems to identify areas with high pollution levels. This information can be used to implement traffic control measures, reroute traffic, or develop emission reduction strategies to minimize pollution hotspots.
7. Research and Policy Development: Long-term data collected by IoT-based air quality monitoring systems can be used by researchers and policymakers to understand air pollution patterns, evaluate the effectiveness of environmental policies, and develop strategies to mitigate pollution and improve air quality.
8. Personal Health and Fitness: IoT devices that monitor air quality can be integrated into wearable health trackers, providing individuals with real-time information about the air they are exposed to. This data can help users make informed decisions about their activities and avoid areas with poor air quality.
9. Agriculture: IoT-based air quality monitoring can benefit agricultural practices by monitoring air pollution levels around farms and greenhouses. This data can help optimize crop production, protect livestock health, and ensure the quality of agricultural products.
10. Citizen Engagement: Air quality monitoring systems can engage citizens by providing real-time data through mobile applications or websites. This empowers individuals to make informed choices, such as avoiding heavily polluted areas or adjusting their activities based on air quality conditions.

Air pollution is one of the biggest threats to the present-day environment. Everyone is being affected by air pollution day by day including humans, animals, crops, cities, forests and aquatic

ecosystems. Besides that, it should be controlled at a certain level to prevent the increasing rate of global warming. This project aims to design an IOT-based air pollution monitoring system using the internet from anywhere using a computer or mobile to monitor the air quality of the surroundings and environment. There are various methods and instruments available for the measurement and monitoring quality of air. The IoT-based air pollution monitoring system would not only help us to monitor the air quality but also be able to send alert signals whenever the air quality deteriorates and goes down beyond a certain level.

In this system, NodeMCU plays the main controlling role. It has been programmed in a manner, such that, it senses the sensory signals from the sensors and shows the quality level via led indicators. Besides the harmful gases (such as CO2, CO, smoke, etc) temperature and humidity can be monitored through the temperature and humidity sensor by this system. Sensor responses are fed to the NodeMCU which displays the monitored data in the ThingSpeak cloud which can be utilized for analyzing the air quality of that area. The following simple flow diagram

indicates the working mechanism of the IoT-based Air Pollution Monitoring System. Air is getting polluted because of the release of toxic gases by industries, vehicle emissions and increased concentration of harmful gases and particulate matter in the atmosphere. The level of pollution is increasing rapidly due to factors like industries, urbanization,

increase in population, vehicle use which can affect human health. Particulate matter is one of the most important parameters having a significant contribution to the increase in air pollution. This creates a need for measurement and analysis of real-time air quality monitoring so that appropriate decisions can be taken in a timely period. This presents real-time standalone air quality monitoring. Internet of Things (IoT)is nowadays finding profound use in each and every sector, plays a key role in our air quality monitoring system too. The setup will show the air quality in PPM on the webpage so that we can monitor it very easily.

In this IoT project, we can monitor the pollution level from anywhere using your computer or mobile.

The explanation of the Air Quality Index (AQI) and its standard ranges are described in [1]. From 0-100 ppm the atmosphere is safe for living. If the ppm level increases above 100 then it moves out of the safety zone. If the ppm value rises above 200 then it becomes extremely dangerous for human life. The DHT11 sensor module is used to measure the temperature and the humidity of the surroundings [2]. The MQ-135 gas sensor is used to measure the air quality of the surroundings [3]. It can be calibrated with respect to fresh air, alcohol, carbon dioxide, hydrogen and methane. In this project, it has been calibrated with respect to fresh air [9], [10]. In [4] the controlling action of NodeMCU has been described. This research has shown the uses of C++ as the programming language for scripting the software code. It has an inbuilt Wi-Fi module which allows the project to implement IoT easily. Arduino IDE is used

to implement the coding part of the project [5], [8]. ThingSpeak cloud is used for the cloud service. It has a free version which requires a delay of 15 seconds to upload an entry in the cloud [6], [7]. As this project uses two sensors, both of them have internal heater elements and withdraw more power(P=V\*I), so though both sensors are turned ON, their output

voltage levels vary and show unpredictable values due to insufficient power drive. So, we used a separate power supply for the sensors as NodeMCU alone is not sufficient to drive two sensors [9].

The Internet of Things (IoT) describes the network of physical objects—“things”—that are embedded with sensors, software, and other technologies for the purpose of connecting and exchanging data with other devices and systems over the internet. These devices range from

ordinary household objects to sophisticated industrial tools. The field has evolved due to the convergence of multiple technologies, including ubiquitous computing, commodity sensors, increasingly powerful embedded systems, and machine learning. Traditional fields of embedded systems, wireless sensor networks, control systems,

automation (including home and building automation), independently and collectively enable the Internet of things. In the consumer market, IoT technology is most synonymous with products pertaining to the concept of the "smart home", including devices and appliances

(such as lighting fixtures, thermostats, home security systems, cameras, and other home appliances) that support one or more common ecosystems, and can be controlled via devices associated with that ecosystem, such as smartphones and smart speakers. IoT is also used in

healthcare systems. There are a number of concerns about the risks in the growth of IoT technologies and products, especially in the areas of privacy and security, and consequently, industry and governmental moves to address these concerns have begun, including the development of international and local standards, guidelines, and regulatory frameworks. IoT devices are a part of the larger concept of home automation, which can include lighting, heating and air conditioning, media and security systems and camera systems. Long-term benefits could include energy savings by automatically ensuring lights and electronics are turned off or by making the residents in the home aware of usage. A smart toilet seat that measures blood pressure, weight, pulse and oxygen levels. A smart home or automated home could be based on a platform or hubs that control smart devices and

appliances. For instance, using Apple's HomeKit, manufacturers can have their home products and accessories controlled by an application in iOS devices such as the iPhone and the Apple Watch. This could be a dedicated app or iOS native applications such as Siri. This can be demonstrated in the case of Lenovo's Smart Home Essentials, which is a line of smart home devices that are controlled through Apple's Home app or Siri without the need for a Wi-Fi bridge. There are also dedicated smart home hubs that are offered as standalone platforms to connect different smart home products and these include the Amazon Echo,

Google Home, Apple's HomePod, and Samsung's SmartThings Hub. In addition to the commercial systems, there are many non-proprietary, open-source ecosystems; including Home Assistant, OpenHAB and Domoticz. Significant numbers of energy-consuming devices (e.g. lamps, household appliances, motors, pumps, etc.) already integrate Internet connectivity, which can allow them to communicate with utilities not only to balance power generation but also helps optimize the energy

consumption as a whole. These devices allow for remote control by users, or central management via a cloud-based interface, and enable functions like scheduling (e.g., remotely powering on or off heating systems, controlling ovens, changing lighting conditions, etc.).The smart grid is a utility-side IoT application; systems gather and act on energy and power related information to improve the efficiency of the production and distribution of electricity. Using advanced metering infrastructure (AMI) Internet-connected devices, electric utilities not only collect data from end-users but also manage distribution automation devices

like transformers. Another example of integrating the IoT is Living Lab which integrates and combines research and innovation processes, establishing a public-private-people-partnership. There are currently 320 Living Labs that use the IoT to collaborate and share knowledge between

stakeholders to co-create innovative and technological products. For companies to implement and develop IoT services for smart cities, they need to have incentives. The governments play key roles in smart city projects as changes in policies will help cities to implement the IoT

which provides effectiveness, efficiency, and accuracy of the resources that are being used. For instance, the government provides tax incentives and cheap rent, improves public transport, and offers an environment where start-up companies, creative industries, and

multinationals may co-create, share a common infrastructure and labor markets, and take advantage of locally embedded technologies, production process, and transaction costs. The relationship between the technology developers and governments who manage the city's assets is key to providing open access to resources to users in an efficient way.

In this project, we have tried to implement the concept of IoT to monitor the temperature, humidity and air quality of the surroundings

In this project IoT based on measurement and display of Air Quality Index (AQI), Humidity and Temperature of the atmosphere have been performed. From the information obtained from the project, it is possible to calculate Air Quality in PPM. The disadvantage of the

MQ135 sensor is that specifically it can’t tell the Carbon Monoxide or Carbon Dioxide level in the atmosphere, but the advantage of MQ135 is that it is able to detect smoke, CO, CO2, NH4, etc harmful gases.

After performing several experiments, it can be easily concluded that the setup is able to measure the air quality in ppm, the temperature in Celsius and humidity in percentage with considerable accuracy. The results obtained from the experiments are verified through

Google data. Moreover, the led indicators help us to detect the air quality level around the setup. However, the project experiences a drawback that is it cannot measure the ppm values of the pollutant components separately. This could have been improved by adding gas sensors for different pollutants. But eventually, it would increase the cost of the setup and not be a necessary provision to monitor the air quality. Since it’s an IOT-based project, it will require a stable internet connection for uploading the data to the ThinkSpeak cloud. Therefore, it is possible to conclude that the designed prototype can be utilized for air quality, humidity and temperature of the surrounding atmosphere successfully.