Technological Advancements in Air Pollution Monitoring Systems: A Review

Avnish Bora, Laxmi Chaudhary

Abstract— **Air pollution is one of the major issues in the current scenario of the technologically advanced world environment due the effects on the environment. Air is polluted due to various industrial, transportation and production activities. The contaminated air with harmful gases becomes serious risk to all the living creature and plants on earth. It has become essential activity to monitor and control of the air pollution in the industrial and metropolitan areas. Many conventional monitoring approaches are being used for the evaluation and controlling of air quality. But there is need of efficient and real-time systems air quality monitoring models which collect information about the concentration of air pollutants and also give assessment of the air pollution of the monitored area. This paper reviews the study of air pollution factors, air pollutants and various air monitoring methods. It also includes the brief study of the advance technologies like Internet of Things' (IoT) with various sensors and Machine Learning (ML) based Artificial Intelligence (AI) model for the air quality data collection and analysis of the data for prediction and control of the air pollution.**

Index Terms*— *Air pollutants, monitoring, sensors, IoT, AI, ANN

I. INTRODUCTION

The population growth, urbanization, automation and economic development have given rise to industrial activities, use of vehicles and energy consumption in most of the cities around the world which led to air pollution. Air pollution has a huge impact on healthy life of all creature and living being on the earth. Air pollution not only a problem for human being living in smog-choked cities but due to global warming and deletion of ozone layer, other organisms, such as animals and plants are highly affected The different types of gases, solid or liquids within air released causes air pollution, and directly affect the health of living beings and also harm or disturb other feature of the environment [2]. The harmful amounts of sulphuric and nitric acids carried out by rain, fog, snow or wind in form of acid rain on Earth. These acids damages tree and make soils and water bodies to acidify, and that makes the water of the lakes, rivers, and soils polluted and ultimately damage wildlife and forests which are dependent on nature. The toxic pollutant in the air, that can impact wildlife in many ways, humans, animals can experience health problems due to exposure to those pollutants in air[5],[8]. The increase of air pollutants in the air due to the transportation, global warming, population density, and changes in the climatic condition has raised the air pollution to dangerous level[1]. So it becomes mandatory to monitor and control the air pollution that makes the environment unhealthier and nontoxic for all the human beings, animals, and the plant life.

Many environmental protection agencies, social workers and government have taken great efforts to reduce the effect of air pollution. Other than that many researchers, developers, policy makers and inventors are utilizing the information of air contamination levels and use this data to minimize, manage and try to improve the living atmosphere [5]. Generally the air quality is monitored and examined by the conventional air monitoring stations and these stations are either automatic or manual that measures the various pollutants in the air [8]. The conventional monitoring system consist of, relative humidity controllers, temperature regulators air filters and calibration instruments. But these monitoring devices and their maintenance are of huge size, heavy weight, very costly and requires high power consumption [4].So advancement in technology and research, has led to the alternatives approaches for monitoring and measuring the air contaminants. This paper describes study of the existing on air quality monitoring n and prediction using the convention monitoring and new advance techniques and approaches.

II. AIR POLLUTANTS

The air may contain natural decomposition of substances, energy, and / or components but there may saturation at certain level in the air and so the pollution occurs due to addition of these substances or other components. The basic air pollutants namely particulate matter (PM), ozone (O3), nitrogen dioxide (NO2), carbon monoxide (CO), sulfur dioxide (SO2), and lead (Pb) [4]. Here these pollutants directly affects the human health as SO2 pollutants cause cardiovascular disorders and can lead to greenhouse effect and acid rain which damages environment [3]. The places nearby the industrial area and crowded traffic areas are more affected by air pollution. The air pollution also cause the breakdown of ozone (O3) which may increase UV radiation and which may damage the vegetation, agricultural crop and commercial forest harvests and plants . As per the data available from the Central Pollution Control Board (CPCB) approximately 51% the air pollution in India is caused by industries, 27 % approx. by vehicles and, 17% and 5% by crop burning and diwali fireworks respectively[2],[7] . Other pollution sources are burning of fossil fuels, agricultural activities, Mining Operations , Indoor Air Pollution etc.

TABLE 1. TYPES OF THE AIR POLLUTANTS [7]

S. No.	Pollutants	Sources
1.	PM10(Particu lar Matter)	Vehicle, Manufacturing Industries, Power plants, industries, and automobiles
2.	NH3(Gaseo us	agriculture, animal husbandry and NH3- fertilizer
3.	NOx(Nitrogen Oxides)	Petroleum refineries,Basic metal
4.	CO (Carbon monoxide)	Manufacture of chemicals, Basic metal industries ,Petroleum refineries,, Electricity, gas and steam, Transport, Crop burning
5.	SO2 (sulphur dioxide)	Manufacture of chemicals, Petroleum refineries, Electricity, gas and steam Transport, Basic metal
6.	O3	Gases from aerosol spray cans and refrigerants
7.	Benzene, Toluene,	Vehicles, Manufacturing

III. AIR POLLUTION MONITORING METHODS

The pollutant levels in the air can be used to find the gas levels and other high level impurities using the monitoring methods. Monitoring of pollutant levels in the air is essential to find out how much that gas levels and particles can cause air pollution [4],[11]].The monitored parameter can be used for air pollution modelling that describes the use of mathematical theory to recognize and prediction can be done the behaviour of the pollutants in the atmosphere. Further these data analysed can be used for prevention and control of the air pollution factors in order to safeguard the environment [13].

A. Continuous monitoring

In the continuous monitoring and measurement of the elements in air may be measured by by spectroscopic, optical, electro-chemical or other methods which gives a uninterrupted indications and concentration records (such a system shows rapid or short term variation of the concentration). Long term concentrations available through sampling can be the average over extended periods (weeks or months). This method requires high level of precision in measurement and detection and for good quality data, more calibration, maintenance and operational and quality control procedures are required and is very expensive monitoring methods [4][13].

B. Meteorological monitoring

As weather is the important factor that may be affected with the concentration in air pollutant and the air quality can be monitored using the meteorological monitoring. Parameters like wind speed, wind direction and air temperature along with the solar radiation, relative humidity, rainfall and a temperature is also being measured by meteorological monitoring [12]. The air movements are affected by the air pollutant concentration so the with the weather reports of a particular place the air pollution can be studied. Strong winds may disperse the pollutants and minimizes the concentration of impurities in air and the pollutants cannot be dispersed the air is still. Meteorological data may be used to recognise the source of pollutant and inversions and high-pollutant concentration days can be predicted in air pollution events [13].

C. Open-path monitoring systems

Open-path monitoring system uses the method absorption of a light beam send over distances of up to the kilometres range in order to measure the various in the air. This system keeps the record of the average concentration on basis of all received contaminants over the complete measured distance instead of taking the particular point. This kind of method is normally preferred in the areas of along site boundaries of industrial and manufacturing processes fields. The advantage of this method is that it includes wide variety of different contaminant and volatile organics which can be used for the research purposes Tis method is costly as compare to other traditional methods [14].

IV. TECHNOLOGICAL ADVANCEMENTS

Due to the large size, limited data access and high cost the researchers and developers are attracted towards other monitoring techniques based on new technologies [19]. These new techniques include the systems designed with advance sensors and detecting a device which provides the accurate, precise and large fraction of data of the air pollutants. These data can be communicated using the IoT(Internet of Things) and wireless sensor networks through the internet connectivity[17] .The collected data can be studied, processed and analysed with the help of various modelling techniques in new technology using the Machine Leaning and Artificial Intelligence. The monitoring and modelling done with the recent technologies provide progress and development of universal multi-pollutant indicators for the health monitoring and economic effects of air pollution and also helps to take measures to control and address the improvement of air quality within the environment[15][23].

A. IoT technology

The one the latest technology named as Internet of Things (IoT) uses the internet or computing and communication and integrate the resources, devices, including sensors and machines and the smart systems. IoT technique use smart devices and sensors to monitor the environmental conditions and the wireless gateways are used to route the sensors data to the Internet. IoT application in air quality monitoring includes the data collection though various sensors across the city and measure the levels of pollutants in the air in order to control, manage and prevent the air contamination level. Various sensors as gas, humidity, temperature, oxygen, particle and dust sensors are placed at different locations to sense the level of sulphur dioxide, carbon monoxide, dust, particles, nitrogen dioxide and other impurities in the air[16]. The information is communicated means wireless mediums for communication which furthers forward it to cloud data database and the air quality information is available on the basis of analysed data. The Wireless sensor network is used in the IoT application to collect the air quality information using LoRa Wi-Fi, Bluetooth, Zig-bee, GPRS , GPS as the communication mediums[15]. IoT application has provide the air quality monitoring with large coverage areas, low cost, identification of pollution hotspots, decision making ,precise data and sharing of data to everyone[17].

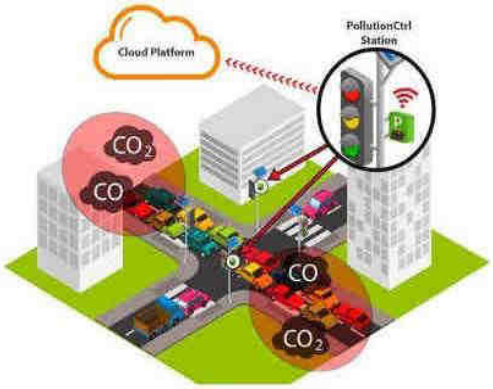

Fig. 1. IoT platform for Air pollution detection

The air pollution level is generally tracked by the Air Quality Index [AQI] The table No. below shows the air pollution level with AQI classes.

TABLE 2.AQI CLASSIFICATION[23]

AQI	Air Pollution Level
0-50	Excellent
51-100	Good
101-150	Lightly Polluted
151-200	Moderately
201-300	Heavily Polluted
300+	Severely Polluted

Daily air quality data across cities has been reported in the work [21] the hourly pollutants data have been collected as shown in Fig.2

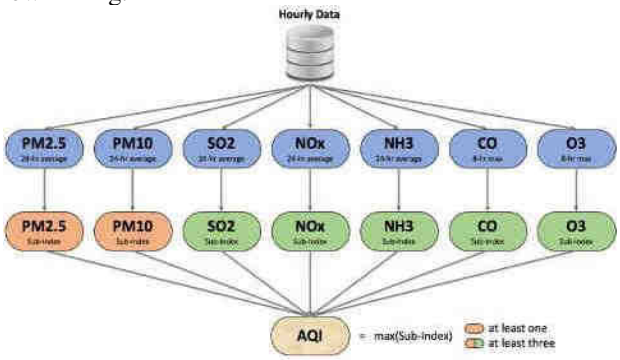

Fig.2 Hourly Data Collection from sensors [21]

Modern day computing advancements have made it easier in monitoring the quality index parameters. The availability of data from the IoT technology has generated a larger database that can be used in identification of AQI. The atmospheric pollutants such as PM, NOx, SO2, CO and O3 can be tracked from the available data sets for future predictions. The Fig. from 3.a to e shows the data observed for the Ahmedabad city in India from January to May 1st ,2020[21].

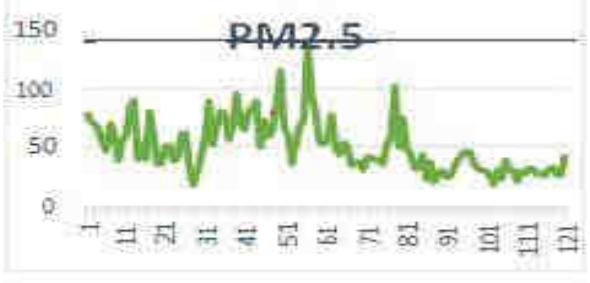

Fig.3.a) PM2.5 measured index

Fig.3.b) NOx measured index

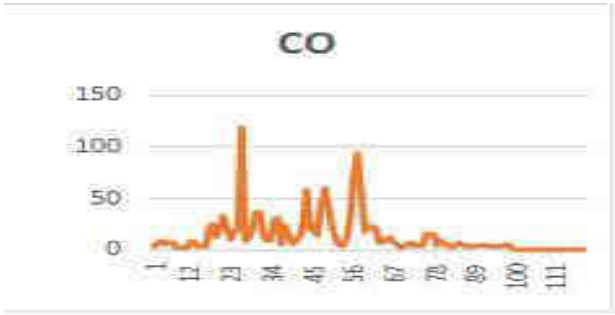

Fig.3.c) CO measured index

Fig.3.d) SO2 measured index

Fig.3.e) O3 measured index

Fig.3 Ahmedabad Five Months daily monitoring of data for 121 days [01.01.2020 to 01.05.2020] PM2.5 b) NOx c) CO d) SO2 e) O3

B. Artificial Intelligence (AI) Technology

The AI model uses the learning capabilities of Artificial Neural Networks (ANNs) that mimics the human brain. Artificial Neural Network model attempts to simulate the capabilities of human brain. Figure shows the basic building blocks of an Artificial Intelligence (AI) based model that can be used for prediction of AQI and Air Pollution levels. The architecture of neural networks consists of different layers, nodes, activation functions which produce a firing signal. The model uses the input from sensor data that are different pollutants as shown in graphs. These are compared with the

Central Pollution Control Board (CPCB) standard norms for AQI monitoring and prediction. The ANN is first trained with the standard data parameters and in the testing phase the real time predictions can be made. The performance of the model can be determined by various metrices such as Mean Square Error (MSE) , Correlation coefficient and root mean square error.

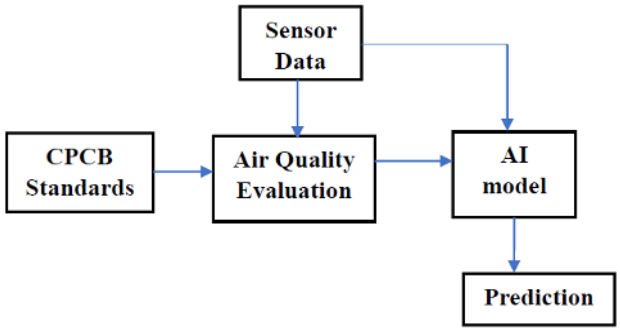

Fig. 4 Artificial Intelligence (AI) based model for AQI

CONCLUSION

Air pollution is serious issue in the environment of industrial and urban areas and so the monitoring requires more observations and critical analysis of the air quality parameters. With the deployment of advance IoT infrastructures with various sensor and devices give the real-time air quality monitoring and routing of the collected data to through the wireless networks. The machine learning based AI model can be used to analysis and evaluate the air quality parameter required for the future smart cities. These new technologies have small devices and low cost sensors, are energy efficient and provide the large data access which make the air monitoring and controlling more efficient. Ultimately will help to reduce the air pollution which will reduce the risk of human health issues and will also save the life other creatures and plants in our environment .This in turn, will reduce human health effects of industrial air pollutants and potential damage to other aspects of the environment.

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