Development of Internet of Things (IoT) Based Monitoring of Hazardous Exhaust Compounds in Air - A Review

Shishir A. Bagal[1*], *Nitin* K. Choudhari[2], and *A.* R. Chaudhari [3]

1 Department of Electronics Engineering, Assistant Professor, KDK College of Engineering & Research Scholar at Laxminarayan Institute of Technology, Nagpur (Maharashtra), India

2 Principal, Priyadarshini Bhagwati College of Engineering, Nagpur (Maharashtra), India

3 Associate Professor and Head of Chemistry Department Priyadarshini Bhagwati College of Engineering, Nagpur (Maharashtra), India

Abstract. Presence of pollutants in Air is the most prominent problem globally confronted now a day. The extreme use of fueled vehicles and rapid urbanization has deteriorated the air quality. This deteriorated air contains hazardous compounds like Mono-oxides & Di-oxides of carbon, Sulphur, Nitrogen, Atmospheric Particulate Matter. Exposure to such hazardous compounds in the air for a long time can cause damage to the human health. Traditional air monitoring systems consists of monitoring stations. As far as traditional air quality monitoring methods are concerned, they are highly expensive and requires a regular maintenance. Due to these limitations, these stations are deployed in small numbers and also it provides indicative values of the sensed data. This monitored data has low resolution and precision. This paper proposes framework for the development of smart and portable system using Internet of Things (IoT) for monitoring of hazardous exhaust compounds in the air using real time. This framework consists of different types of sensors and a controller that are used for monitoring and assessment of the air quality. Also it is used to check the presence of hazardous compounds emitted by different industries and share this data through IOT. The outcome of the proposed research work can be utilized by industries as well as by other agencies to carry out an audit of hazardous exhaust components present in air, so as to take necessary precautions and to save human.

Keywords – Hazardous Exhaust Compounds, Particulate Matter, Internet of Things (IoT), Real Time Monitoring, World Health Organization (WHO), Sensors.

1. Introduction

During past few decades, world has witnessed tremendous Industrial growth and rapid urbanization. Due to this industrial growth, employment has increased manifold. On the

* Corresponding Author: shishirabagal@gmail.com

other hand it has also contributed to the release of hazardous compounds in the air. Due to great pace of Urbanization & industrial growth, environment has witnessed deterioration of the quality of air. The boundless use of crude oil private and commercial vehicles as well as machines in the industries, discharge a large amount of perilous gases and gaseous particles matter in the air. Pure Air is important ingredient of life for every individual. Theses hazardous exhaust compounds released in Air affects the health and overall development of human being [1].

Air in the atmosphere contains heavy metals and hazardous exhaust compounds along, polluting water and agricultural land. Therefore, Release of hazardous exhaust components and particulate matter from exhausted air from vehicles and industries is not a issue of entirely industrial regions but a global problem which influences everyone in the society along with effect on environment [2]. As per the report of World Health Organization (WHO), Out of total population of the world, around 92% used to live in the areas that has presence of such hazardous exhaust compounds. In addition, the report also states that the presence of Hazardous exhaust compounds, particulate matter & hydrocarbons in the exhausted air is the big environmental risk to health of every individual. Moreover, the statistic shows 3 million deaths annually are causing due presence of hazardous exhaust compounds in the air [3].

Moreover, the number of vehicles commuting on the roads and excessive use of conventional energy sources is one of the major factors for releasing the hazardous exhaust compounds air. There are different types of hazardous exhaust compounds exhausted in air by varied sources, These includes Mono-oxides & Di-oxides of carbon, Sulphur, Nitrogen, gaseous Particles i. e. Perticulate Matter (PM for short) which is having diameters less than or equal to 10 μm is PM10 and the other having diameter less than or equal to 2.5 μm is PM2.5 [4]. It is the Particulate Matter PM2.5 that affects the human with respiratory dieses and may damage the lung or heart.

Constant human exposure to such Hazardous exhaust compounds may invite several health problems based on the exposure duration to it, type of hazardous compounds, and the level of such compounds. The WHO has recommended standard of air quality that demonstrates the effects on health from various hazardous compounds present in the discharged air from industries and societies [4]. Different health effects of theses hazardous exhaust compounds are difficulty in breathing, suffocation, nausea or Irritation of skin etc. The mainly occurring health issues are weakened lung functioning, asthma, respiratory diseases and premature death [5].

Therefore, Innovative system for monitoring the Hazardous exhaust compounds in the exhausted is the need of the hour, so that harm to the human health and ill effects on the environment can be reduced. Moreover, these monitoring systems will help the industries to keep the track of these hazardous exhaust compounds for audit and also and government / other agencies to prepare the policies to healthy environmental conditions for all.

2. Related Work

Though, sufficient work has been carried out as far as Monitoring of hazardous exhaust compounds in air is concerned using different techniques. But still there is a scope of research to address various untouched hazardous compounds. The intense need for system, that shall monitor the presence of hazardous exhaust compounds in air motivated for the

development of the system that is capable of monitoring and assessing the future trends of various hazardous exhaust compounds in air.

Being an essential part, this section outlines the contribution of various research work based on different technologies.

In its work S. Muthukumar et'al [6] proposed a pollution monitoring system, which only monitors the vehicular pollution using different types of sensors. The proposed system is based on IoT and is used to gather the real time values of air pollutants like SO2, CO, CO2, NO and also calculates the percentage of these pollutants. The pollutants that are addressed by the proposed systems are ammonia, oxygen and carbon monoxide etc.

The model for assessing the complexity of air pollution was proposed by Chen Xiaojun et'al [7] in their work air pollution monitoring and forecasting system. It uses several sensors and neural network for monitoring and prediction of the pollutants like temperature, humidity, wind direction, wind speed.

Jen-Hao Liu et'al [8] presented a framework for monitoring air quality. The system is based on wireless sensor networks (WSNs) and global system for mobile communications (GSM). The proposed system only monitors the carbon concentration in air. The LabVIEW program developed is used to manage the system that consists of nodes for sensors, a gateway, and a control center. The data acquired and maintained at the control center.

An intelligent IoT model based on Petri Nets (PN) was proposed by Ahmad F. Subahi [9] for monitoring of temperature and guessing the reference temperature that can be used for temperature regulation block. It also put an emphasis on the energy consumption and efficiency of the model.

An IoT based monitoring system was proposed by Zhibin Liu1 [10] using Zigbee for monitoring of indoor air quality which monitors PM2.5, CO_2, temperature & humidity. The data collected through IoT devices are shared using GPRS / 4G Network. The model monitors the temperature and makes the guessing of the reference temperature that can be used for temperature regulation block. It also put an emphasis on the energy consumption and efficiency of the model.

A Low-cost, open IoT system for carbon Dioxide monitoring in indoor classrooms was proposed by Rafael Fayos-Jordan [11], which consists of an IoT based system that has open hardware and open-software and architecture in order to measure the CO2 concentration, temperature and relative humidity.

An IoT based models were proposed for monitoring of various hazardous pollutants in air, sound, Water and Soil by different authors [12][13][14][15] [16]. These models use different types of controllers and sensors for data acquisition and monitoring. These models are capable of monitoring different compounds of pollutants present in air, sound, Water and Soil like various hazardous compounds in air, PH value in industrial effluents etc.

A real time system to monitor and analyze air quality is designed that record the data remotely to the server, and update the data via the internet was proposed by Kennedy Okokpujie [17] The proposed system was developed using an Arduino microcontroller and it monitors the presence of gaseous, dust pollutants present in air & its level [18] [19].

Fulvio Corno et'al [20] introduces the IoT crowd-sensing platform using bicycle networks as IoT to provide various services to citizety. The platform is based on research work to guess the most interesting bike-friendly services. This system incorporâtes the services like real-time remote geo-location identification of the bike, tracing of theft and air pollution observation. This information is routed and shared using IoT platform.

Air quality monitoring system for Real-time and based IoT with mobile sensing in metropolitan areas was published by Srinivas Devarakonda et al [21]. This system comprises of two models one is installed on public vehicle and other is installed on personal vehicle. Data of Air quality obtained with such acquisition models can be used for a variety of purposes. Patients having respiratory or cardiovascular health issues will find these results valuable in determining less congested routes [20][21].

A structured overview of guidelines of existing air quality and standards in force by diefferent juridictions are presented by He Zhang [22]. It also outlined a review and analysis of low-cost, state-of-the-art air quality sensor (LCAQS) systems with relevant specifications such as Range of detection, tolerance measurement, resolution and response time [22] [23].

Table 1. Sensors used for different processes in various Plants emitting Hazardous Exhaust.

Plant process	Parameter	Common sensor technologies
Furnace	Coal flow	microwave-based / Electrostatic
	Combustion air flow	thermal mass flow meters, Venturis, Pitot tubes
	Temperature	Thermocouple, IR / acoustic pyrometry,
	Oxygen	Electrochemical cell / paramagnetic
	CO	catalytic bead , NDIR, or TDLAS
	Presence/quality of flame	Ultraviolet / IR detector, optical imaging
	Heat flux	thermocouple or RTD-based , Heat flux sensors
Steam cycle	Feedwater pH	Electro-chemical
	Feedwater O2	Electro-chemical / polarographic cell
	Feedwater solids	Specific conductance based
	Drum level	optical / Radar sensors,
	Steam temperature	RTD / Thermocouple
	Steam pressure	Bourdon tube, piezoelectrics, diaphragm gauge
	Steam flow	Coriolis meter, vortex meter, Venturi
Emissions monitoring and pollutant control	NO and NO2 SO2	CLD, Ultraviolet photometry, electrochemical cell NDIR, FTIR
	Hydrocarbons	Flame ionisation detector

	CO	NDIR, catalytic bead
	Particulates	Optical opacity
	NH3 slip H2/CO2/CH4	Ultraviolet photometry, diode laser/mid-IR absorption Thermal conductivity detector
	Limestone slurry pH	Electrochemical
	Mercury	Ultraviolet absorption
	Carbon-in-ash	Microwave-based
Coal mills	Coal moisture	Microwave-based LIBS, PGNAA
	Coal elemental composition Particle size	Optical
	Coal flow	Electrostatic or microwave-based
Steam turbine	Main valve position	LVDT
	Blade tip timing and clearance	Optical, eddy current, capacitive
Auxiliary machinery	Temperature Vibration	RTD, thermocouple Accelerometer

A structured analysis of the latest systems for the monitoring of indoor air quality using Internet of Things is provided by Jaguriti Saini et al [24]. This document also highlights design considerations for surveillance systems, which highlights different types of sensor, a siutable controller based architecture and connectivity and implementation issues. Also, it addresses the different types of sensors i. e. Thermal sensor, gas sensors for detection of multiple or single gas, along with dust sensor [24] [25].

Sarath K. Guttikunda et'al [26] [27] presented a survey on discharge of Atmospheric emissions and pollutants by thermal power plants that are governed by coal-fire in India and Air pollution knowledge assessments (APnA) for 20 Indian cities. Their study also provides important information about consumption of coal in thermal power plants and pollutants that are being generated along with surveys of 20 major cities in india against air pollution due to varied sources.

Table 2. Consumption of coal in thermal power plants and pollutants.

City name	Domain pop	Urban pop	Airshed grids	Airshed area	Urban area	Built-up area (sq.km)	
%	million	%	#X . #Y	Sq.Km	%	1975	2014
Agra	4.1	91%	40 × 40	2230	26%	18	107
Amritsar	2.3	85%	40 × 40	2327	27%	65	119
Bengaluru	11.9	93%	60 × 60	4574	27%	147	631
Bhopal	2.7	97%	40 × 40	2157	26%	47	141

Bhubaneswar	3.7	88%	30 × 50	1982	27%	17	118
Chandigarh	5	85%	60 × 60	5176	27%	300	420
Chennai	10.7	93%	50 × 50	3177	27%	108	522
Coimbatore	3	88%	50 × 50	3156	19%	42	224
Dehradun	1.2	88%	40 × 20	1149	19%	18	59
Indore	3.1	93%	40 × 40	2150	28%	28	247
Jaipur	4.8	94%	40 × 40	2223	28%	48	294
Kanpur	5.2	90%	40 × 30	1661	26%	25	190
Kochi	3.9	94%	40 × 40	2012	26%	135	374
Ludhiana	2.8	87%	40 × 40	2310	28%	122	233
Nagpur	3.7	96%	40 × 40	2125	27%	123	240
Patna	5.3	85%	60 × 30	2473	19%	22	85
Pune	6.9	97%	40 × 40	2091	28%	46	280
Raipur	3.2	87%	60 × 30	2390	19%	110	314
Ranchi	1.9	87%	40 × 40	2159	22%	19	71
Varanasi	4.2	71%	40 × 40	2193	16%	37	100

The major concern of a pollution monitoring system based on real-time includes various types of sensors, use of Internet of Things (IoT) and communication protocols, capturing the data and its transmission across communication channels, security of data and it's consistency.[28].

3. Proposed Methodology

In the proposed work, it is intended to develop a hardware model that will monitor presence of hazardous compounds that industries exhibit in societal area. Here the concept is to use the potential of Internet of Things (IoT) for monitoring the monitor presence of hazardous compounds. This framework proposes an air quality observing framework that enables us to monitor and check the presence of hazardous compounds emitted by different industries through IOT and give alert of precaution to all concerned.

Steps involved in the Air & Noise Pollution Monitoring: -

1) Sensor will sense the different hazardous components present in the air.
2) The Sensor output is given to the signal conditioning for converting it in to appropriate level.
3) The output of signal conditioners is given to the IoT controller.
4) IoT controller will process & compare the input samples with that of the standard Parameters available in the database
5) IoT controller will record levels of hazardous exhaust compounds present in an air which can be utilized to develop correlations
6) The system will be validated and if required, it will be modified accordingly.

7) The proposed system will be used to provide benefit to different industries and society with the rapidly increasing use of internet IoT (Internet of Things).

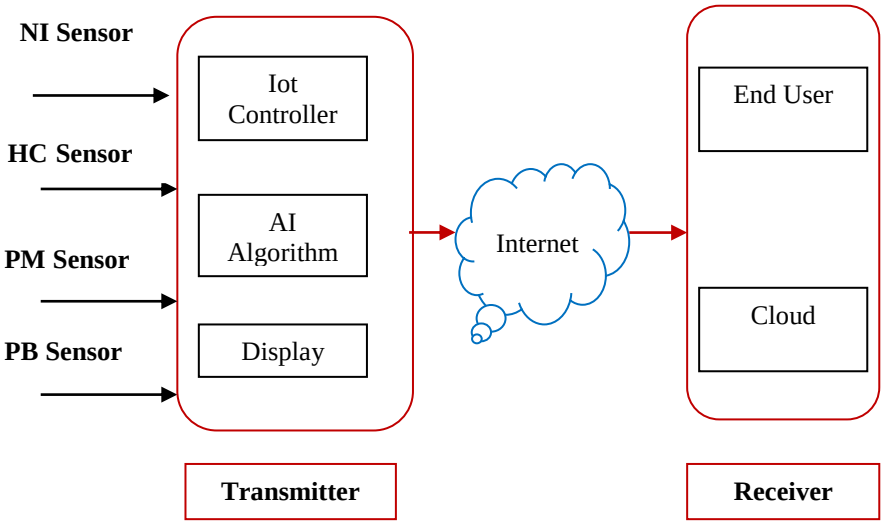

Fig 1. IoT Based System for Monitoring Hazardous Exhaust compound in air

IoT is nothing but the interconnected devices network, which are supported with different kinds of sensors, software architecture, connectivity and necessary electronics circuits to gather and exchange information to make the system more interactive and responsive. Internet of Things (IoT) is basically a architecture in which information exchange and integration allowed between the end user systems and physical world using the existing network[12][13].

The proposed monitoring system consists of Nickel Sensor, HC Sensor, Lead Sensor, & PM2.5 Sensor. It also consists of IoT controller, Wi-Fi module, Cloud, End user System and Internet Connectivity etc. The tentative block diagram of proposed IOT based monitoring system for hazardous exhaust compounds in air is shown in fig. 1 above

3.1 Sensors

Block diagram above shows the different sensors for sensing and reading sample values of various hazardous compound present in the air. Sensors read the value of the physical parameter and convert it in to equivalent electrical form

3.2. Data Acquisition

This block is responsible for converting the sample values read from the sensor compatible with the next block i. e. IoT Controller. The samples thus read from the sensors are conditioned and by the data acquisition block.

3.3. IoT Controller

IoT Controller is basically a combination of controller and internet connected physical devices. Controller is used to process the sample values read from the sensors. These processed sample values are then fed to the end user devices using internet for creating the data base. Also these sample values can be stored on the cloud.

3.4 AI Algorithm

Artificial Algorithm will be incorporated to analyze the sample values and use the appropriate algorithm to predict the future trend of the presence of hazardous exhaust compounds in air.

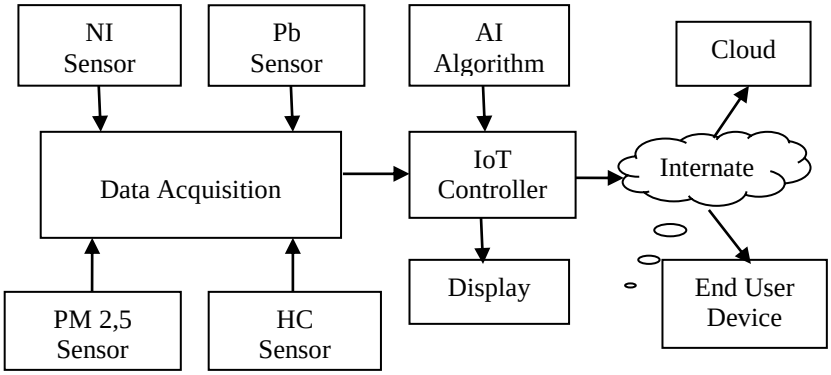

Fig.-2. Block Diagram of Proposed System

4. Conclusion

Detection of different types of hazardous compounds present in the air that is exhausted from various industries is a very essential. This will help in order to reduce harm / damage caused due these hazardous compounds to the human being. The Ambient Air Quality Monitoring Systems (AAQMS) are installed in urban areas by the Pollution Control Agencies in India. These systems require high Installation and Maintenance cost. Therefore, these systems are difficult to install at every industry.

This article portrays an outline for the development of Smart & Low cost, IoT based system for monitoring of hazardous exhaust compounds from various industries. The system in consideration will Collect the air samples of the exhausted air and analyze these samples. Depending on the analysis, it will display the presence of different hazardous compounds in the Air along with their concentration. The proposed system will also incorporate the Artificial Intelligence (AI) based algorithm to estimate the future trends of these hazardous compounds. This will help the concerned industry to take the necessary measures to control the emission of such hazardous exhaust in Air.

Moreover, the system will be capable of creating the data base of such past monitoring. This database will be maintained on central server using cloud and can be shared using Internet of Things (IoT) with external agencies for further analysis or for the pollution audit of the concerned industry.

References

1. Helton Pierre Lucena de Medeiros, Gustavo Girão, "An IoT-based Air Quality Monitoring Platform", © IEEE 2020, IEEE Xplore. (2020)
2. World Health Organization 2010, WHO guidelines for indoor air quality: selected pollutants 2010: benzene, carbon monoxide, formaldehyde, naphthalene, nitrogen dioxide, polycyclic aromatic hydrocarbons, radon, trichloroethylene and tetrachloroethylene. (2010)
3. World Health Organization 2016, Ambient Air Pollution : A global assessment of exposure and burden of disease: Air Pollution, Environmental Exposure, Urban Health, Epidemiologic studies, Cost of Illness. (2016)
4. Ahmed Samy Moursi, Nawal El-Fishawy, Soufiene Djahel, Marwa Ahmed Shouman, 'An IoT enabled system for enhanced air quality monitoring and prediction on the edge", Complex & Intelligent Systems (2021)7:2923–2947, https://doi.org/10.1007/s40747-021-00476-w. (2021)
5. Meruyert Nurgazy, Arkady Zaslavsky, Prem akash Jayaraman, Sylvain Kubler, Karan Mitra and Saguna Saguna, "CAVisAP: Context-Aware Visualization of Outdoor Air Pollution with IoT Platforms", Easy Chair, April 28, (2019).
6. S. Muthukumar, W. Sherine Mary, Jayanthi.S, Kiruthiga.R Mahalakshmi.M, "IoT based air pollution monitoring and control syste", Proceedings of the International Conference on Inventive Research in Computing Applications (ICIRCA 2018) IEEE Xplore Compliant Part Number:CFP18N67-ART; ISBN:978-1-5386-2456-2 (2018)
7. Chen Xiaojun, Liu Xianpeng, Xu Peng, "IOT- Based Air Pollution Monitoring and Forecasting System", International Conference on Computer and Computational Sciences (ICCCS), 2015, 978-1-4799-1819-5/15/$31.00 IEEE 257. (2015)
8. Jen-Hao Liu, Yu-Fan Chen, Tzu-Shiang Lin, Chia-Pang Chen, Po-Tang Chen, Tzai-Hung Wen, Chih-Hong Sun, Jehn-Yih Juang, and Joe-Air Jiang, "An Air Quality Monitoring System For Urban Areas Based On The Technology Of Wireless Sensor Networks", International Journal On Smart Sensing And Intelligent Systems, Vol. **5**, No. **1**, March (2012)
9. Ahmad F. Subahi, And Kheir Eddine Bouazza, "An Intelligent IoT-Based System Design for Controlling and Monitoring Greenhouse Temperature", IEEE Access- June 16,(2020)
10. Zhibin Liu, Guangwen Wang, Liang Zhao, Guangfei Yang, "Multi-Points Indoor Air Quality Monitoring Based on Internet of Things", IEEE Access- March 26, (2021)
11. Rafael Fayos-Jordan, Jaume Segura-Garcia, Antonio Soriano-Asensi, Santiago Felici-Castell, Jose M. Felisi, Jose M. Alcaraz-Calero, "VentQsys: Low-cost open IoT system for CO2 monitoring in classrooms", Wireless Networks (2021)27:5313–5327, https://doi.org/10.1007/s11276-021-02799-5(0123456789-vol V) (2021)
12. Prof. Kaushik Vipul R, Dr. Tanaji Dabade, Dr. Vijay N. Patil, "Iot Based Air And Sound Pollution Monitoring System- A Review", Journal of Emerging Technologies and Innovative Research (JETIR), © 2019 JETIR, Volume **6**, Issue **6** June (2019)
13. Tanuja Borate, Meghalata Lipane, Madhuri Kale, Vaishnavi Pardeshi, Prof. Prashant Jawalkar, "IoT Based Air And Sound Pollution Monitoring System", Open Access Journal of Science and Engineering, Volume **4**, Issue **2**, February (2019)
14. Lalit Mohan Joshi, "Research paper on IOT based Air and Sound Pollution Monitoring System", International Journal of Computer Applications (0975 – 8887) Volume **178** – No.**7**, November (2017)
15. Nishant.V, Vinod Kumar M.S, Dr. Suresh.R, Dr. Mallikarjuna C, "IoT Based Industrial Air, Water And Noise Pollution Monitoring System", International

Research Journal of Engineering and Technology, Volume: **08** Issue: **06** | June (2021)

16. Vivek Waghmare, Aishwarya Hirve, Urmila Dingore, Shubhangi Bhavsar, Ruchika Mahajan, "Internet of Things (IoT) Based System for Monitoring and Controlling Air Pollution. Elixir Comp. Engg. 130 53082 **53082-53084**. (2019)
17. Kennedy Okokpujie, Etinosa Noma-Osaghae, Odusami Modupe, Samuel John, Oluga Oluwatosin, "A Smart Air Pollution Monitoring System", International Journal of Civil Engineering and Technology (IJCIET) Volume **9**, Issue **9**, September (2018)
18. Nael Abd Alfatah Husein, Abdul Hadi Abd Rahman, Dahlila Putri Dahnil,"Evaluation of LoRa-based Air Pollution Monitoring System", International Journal of Advanced Computer Science and Applications, Vol. **10**, No. **7**, 2019 391 | P a g e www.ijacsa.thesai.org (2019)
19. Yu-Lin Zhao, Jiali Tang, Han-Pang Huang, Ze Wang, Tse-Lun Chen, Chih-Wei Chiang,"Pen-Chi Chiang, Development of IoT Technologies for Air Pollution Prevention and Improvement", Aerosol and Air Quality Research, 20: 2874–2888, 2020, ISSN: 1680-8584 print / 2071-1409 online Publisher: Taiwan Association for Aerosol Research https ://doi.org/10.4209/aaqr.2020.05.0255 (2020)
20. Fulvio Corno, Teodoro Montanaro, Carmelo Migliore,Pino Castrogiovanni, SmartBike: an IoT Crowd Sensing Platform for Monitoring City Air Pollution", International Journal of Electrical and Computer Engineering (IJECE) Vol. **7**, No. **6**, December (2017).
21. Srinivas Devarakonda, Parveen Sevusu, Hongzhang Liu, Ruilin Liu, Liviu Iftode, Badri Nath, "Real-time Air Quality Monitoring Through Mobile Sensing in Metropolitan Areas", UrbComp'13, August 11–14, 2013, Chicago, Illinois, USA.Copyright © 2013 ACM 978-1-4503-2331-4/13/08. (2013)
22. He Zhang * and Ravi Srinivasan, "A Systematic Review of Air Quality Sensors, Guidelines, and Measurement Studies forIndoor Air Quality Management", UrbSys (Urban Building Energy, Sensing, Controls, Big Data Analysis, and Visualization) Laboratory, M.E. Rinker, Sr. School of Construction Management, University of Florida, Gainesville, FL 32603, USA;
23. Toby Lockwood, "Advanced sensors and smart controls for coal-fired power plant", IEA Clean Coal Centre 14 Northfields London SW18 1DD United Kingdom.
24. Jagriti Saini, Maitreyee Dutta, Gonçalo Marques, "Indoor Air Quality Monitoring Systems Based on Internet of Things: A Systematic Review", International. Journal of Environ. Res. Public Health 2020, 17, 4942; doi: 10.3390/ijerph17144942 (2020)
25. Cristian Toma, Andrei Alexandru, Marius Popa, Alin Zamfiroiu, "IoT Solution for Smart Cities' Pollution Monitoring and the Security Challenges", Sensors2019,19,3401; doi:10.3390/s19153401, www.mdpi.com/journal/sensors (2019)
26. Sarath K. Guttikunda, Puja Jawahar, "Atmospheric emissions and pollution from the coal-fired thermal power plants in India", http://dx.doi.org/10.1016/j.atmosenv.2014.04. www.elsevier.com/locate/atmosenv, 0571352-2310/_ 2014 Elsevier Ltd. (2014)
27. Sarath K. Guttikundaa,b, Nishadh K.A., Puja Jawahar, "Air pollution knowledge assessments (APnA) for 20 Indian cities", www.elsevier.com/locate/uclim, https://doi.org/10.1016/j.uclim.2018.11.005
28. Cristian Toma, Andrei Alexandru, Marius Popa, Alin Zamfiroiu, "IoT Solution for Smart Cities' Pollution Monitoring and the Security Challenges", Sensors, 19, 3401; doi:10.3390/s19153401, www.mdpi.com/journal/sensors (2019)