

A survey on Air Quality forecasting Techniques

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Abstract-- Air pollution is becoming an environmental threat with the increase in industrialization and urbanization. The air quality is becoming essential both for the environment as well to the society. There are different type of numerical as well as statistical tools for the prediction and analysis of air quality, but Artificial Neural Network is considered to be an excellent predictive and data analysis tool for Air quality forecasting. Hence, this paper focusses on a comprehensive review on existing air quality forecasting techniques through soft computing.

Keywords-- Air quality, Artificial Neural Network, Fuzzy logic, Air pollutants, Software tools for ANN.

INTRODUCTION

Since the beginning of industrial revolution and more rapid acceleration from the past several years as more countries have embarked on rapid development, the composition of the atmosphere has been gradually changing and thus this variation in the composition in the constituents of the atmosphere results in air pollution. Thus, Air Pollution can be defined as the presence of substances in atmosphere insufficient concentrations so that they are threaten to be harmful to human, plant, animal life, and the most drastic damage to the environment and the climatic conditions. In other words it can be said that, air pollution destroys the comfortable enjoyment of life, property and environment. In today's scenario of industrialization, the adverse effect on environmental problems is considered a big problem to both developing and developed countries.

I. AIR POLLUTION

The advancements in technology and rapid change in public requirements/needs leads to industrialization, leads to air pollution, becomes major concern to be predicted and several control methods/strategies should be undertaken to address the adverse effects of air pollution[21].

The insufficient amount of substances that are added to the atmosphere either through man-made or natural processes, called air pollutants. The following are the major originators of air pollutants:

- Indoor air pollutants
- Outdoor air pollutants

A. Indoor air Pollution

In country like INDIA, large population still depends on bio fuels for cooking and heating, resulting indoor air pollution. Indoor air pollutants causes major health disorders to human beings.

B. Outdoor air Pollution

The outdoor pollution is created mainly due to automobiles and various industries. The outdoor air pollutants are responsible for the climatic effect along with the effect on the environmental disparity to social life.

The following are the categories of air pollutants:

- Primary Pollutants.
- Secondary pollutants.

1. *Primary pollutants*: Primary Pollutants results from the combustion of fuels and industrial operations.

2. *Secondary pollutants*: Secondary pollutants are those which are produced due to the reaction of primary pollutant in the atmosphere. Table 1 lists the name of pollutants and their various sources.

TABLE 1
AIR POLLUTANTS AND THEIR SOURCES

POLLUTANTS	SOURCES
SULPHUR DIOXIDE(SO ₂)/SULPHUR OXIDES(SOX)	Power plants, sulphuric acid manufacture, boilers, ore refining, petroleum refining.
SUSPENDED PARTICULATE MATTER, SPM (from sulphates and nitrates)	Fine particles which are added either man-made or naturally. Automobile, power plants, boilers, Industries requiring crushing and grinding such as quarry, cement.
Lead	Naturally occurring, produced by lead smelters, contained in old paints and plumbing. Also in ore refining, battery manufacturing and automobiles.
Chlorine	Chlor-alkali plants, manufacturer of polyvinyl chloride (PVC) resins, bleaching powder and many other chemicals.
Fluorides	Fertilizer, aluminum refining, nuclear industry, steel industry, oil refineries
Oxides of Nitrogen NO, NO ₂ , NO _x	Automobiles, power plants, nitric acid manufacture,
Peroxyacetyl nitrate, PAN	Secondary pollutant
Persistent organic pollutants (POP's)	Produced through industrial processes and waste incineration.
Formaldehyde	Secondary pollutant
Ozone	Secondary pollutant, formed from chemical reaction during sunlight.
Carbon Monoxide	Automobiles, from combustion processes low in oxygen, burning wood, coal, fuel (cars).
Hydrogen Sulphide	Pulp and paper, petroleum refining
Hydrocarbons	Automobiles, petroleum refining
Ammonia	Used to fertilize crops and emitted from this agricultural process and farm animals.
Carbon dioxide	From volcanic activity and hot springs, combustion processes, cars and plants.

III. NEED FOR FORECASTING AIR POLLUTION

The pathways for the transport and transformation of matter within four categorical areas that make up planet Earth (biosphere, hydrosphere, lithosphere, and the atmosphere) are called as Bio-geo-chemical cycle. These cycles governs the functioning of the Earth. The Earth is open to electromagnetic radiation from the sun and outer space, but is a virtually closed system with regard to matter. Thus, the matter enclosed within the Earth from the time of its birth is transformed and circulated geographically. Biogeochemical cycles are natural cycles but due to different types of physical as well as chemical world effects, these cycles are affected. With the rapid changes in these cycles the atmosphere surrounding the Earth, responsible for the existence of life on the planet is affected which in return affects the life on Earth.

Due to such adverse effects, Weather forecasting, an application of Science and Technology is used to predict the state of the atmosphere for different locations. Air

quality models play a vital role in all aspects of air pollution control and air quality planning, where prediction is a major component. Air quality forecasts provide the public with air quality information which allows people to take precautionary measures to avoid or limit their exposure to unhealthy levels of air pollution.

A. EFFECTS OF AIR POLLUTION

As we know, the occurring life existence on Earth is in danger due torapid increase of various effects such as global warming, many healthdisorders that are found in human body as well in animals. Even the food, fruits and vegetables we eat is not safe, it also get affected by various air pollutants. Thus, the study shows that the human beings, animals, plants and the environment surrounding them are all affected by the air pollution and its harmful pollutants. Air pollutants effects on human health and on environment, summarized in the table II.

TABLE II AIR POLLUTANTS EFFECTS

POLLUTANTS	EFFECT ON HUMAN HEALTH	EFFECT ON ENVIRONMENT
Sulphur Dioxide(so ₂)/ Sulphur Oxides(so _x)	<ul style="list-style-type: none"> ➤ Respiratory problems. ➤ Causes irritation to the eyes and skin. ➤ Lung cancer ➤ Cardiovascular diseases and mortality rate. 	<ul style="list-style-type: none"> ➤ Damage vegetation. ➤ Causes Corrosion. ➤ Acid Rain. ➤ Plant and water damage. ➤ Aesthetic damage
Suspended Particulate Matter	<ul style="list-style-type: none"> ➤ Increase in cancer and deaths from respiratory illness. ➤ Decrease in lung fluctuation. ➤ Causes problems like bronchitis, asthma, pneumonia etc. 	<ul style="list-style-type: none"> ➤ Acid deposition in air and water. ➤ Haze in natural areas. ➤ Change in nutrient cycles. ➤ Loss of ecosystem services.
Lead	<ul style="list-style-type: none"> ➤ Destructive behavioural changes, learning disabilities and permanent brain damage. ➤ Loss of appetite. ➤ Stomach discomfort and/or constipation. ➤ Insomnia. 	<ul style="list-style-type: none"> ➤ Causes Lead Poisoning to soil organisms. ➤ Lead intoxication is a common disease found in animals.
Chlorine	<ul style="list-style-type: none"> ➤ Results in coughing, chest pain and also cause water retention in the lungs. 	<ul style="list-style-type: none"> ➤ Chlorine affects the marine life. ➤ It causes damage to ozone layer.
Oxides of Nitrogen NO,NO ₂ ,NO _x	<ul style="list-style-type: none"> ➤ Nitrogen dioxide can irritate the lungs and lower resistance to respiratory infections such as influenza. ➤ Reducing the oxygen carrying capacity of the blood. ➤ Decreased functioning of the thyroid gland. ➤ Causes Asthma, 	<ul style="list-style-type: none"> ➤ Adverse effects on both terrestrial and aquatic ecosystem. ➤ Animals exposed to nitrogen dioxide may experience destruction of cilia, alveolar tissue disruption. ➤ Nitrogen Oxides are precursors for acid precipitation and ozone and each of which cause injury to plants.
Peroxyacetyl nitrate, PAN	<ul style="list-style-type: none"> ➤ Causes irritation to eyes, respiratory system. ➤ People with heart and lung disease, children and the elderly are the most susceptible to PAN. 	<ul style="list-style-type: none"> ➤ Crops are affected. ➤ Winds can carry it to rural regions and pristine areas cause an ecological impact. ➤ Damage to clothes, plants and rubber articles. ➤ Agricultural and forests are affected.
Formaldehyde	<ul style="list-style-type: none"> ➤ It can cause watery eyes, burning sensations in the eyes, and difficulty in breathing. ➤ Health effects include eye, nose, and throat irritation; wheezing and coughing. 	<ul style="list-style-type: none"> ➤ It breaks into carbon monoxide and formic acids which affects the environment. ➤ Causes acid rain.
Carbon Monoxide	<ul style="list-style-type: none"> ➤ At low concentrations, fatigue in healthy people and chest pain in people with heart disease. ➤ At higher concentrations, impaired vision and coordination. ➤ Can cause flu-like symptoms. 	<ul style="list-style-type: none"> ➤ Its presence affects concentrations of other greenhouse gases including methane, ozone and carbon dioxide. ➤ It causes biomass burning.
Hydrogen Sulphide.	<ul style="list-style-type: none"> ➤ It causes neurological, cardiovascular, metabolic, reproductive problems. 	<ul style="list-style-type: none"> ➤ Effects on the life of fishes and other marine organisms.
Ammonia	<ul style="list-style-type: none"> ➤ When combined with water can injure and damage the respiratory tract. ➤ Problems with Bronchitis, asthma and cough 	<ul style="list-style-type: none"> ➤ Soil and freshwater acidification. ➤ aerosol production affecting global radioactive forcing(the greenhouse effect)
Carbon dioxide	<ul style="list-style-type: none"> ➤ Causes headaches, dizziness, breathing problems, sweating, tiredness, increased heart rate, blood pressure, coma, asphyxia, and convulsions. 	<ul style="list-style-type: none"> ➤ A Greenhouse gas, responsible for global warming of Earth.
Ozone	<ul style="list-style-type: none"> ➤ Induction of respiratory symptoms. ➤ Decrements in lung function. ➤ Also, causes throat irritation. 	<ul style="list-style-type: none"> ➤ It reduces crop yield and forest growth, and damages the appearance of leaf.

IV. LITERATURE REVIEW

The prediction of air quality is becoming essential for minimizing the environmental imbalances further effectively addresses the air pollution. There are different type of numerical as well as statistical tools for the prediction and analysis of air pollution. The emergence of advanced computing/analysis techniques from traditional computing methods to recent soft computing techniques are effectively addresses the air quality prediction.

The traditional approach for air quality prediction uses mathematical and statistical techniques. In these techniques, initially a physical model was designed and then data is coded with mathematical differential equations. But such methods suffers from disadvantages like they provide limited accuracy as they were unable to predict the extreme points i.e. the pollution maximum and minimum cut-offs cannot be determined using such approach. Also, such methods were lengthy and inefficient approach for better output prediction[20]. But with the advancement in technology and research, an alternative to traditional methods has been proposed i.e. Artificial Intelligence (AI) techniques can be used for prediction purposes. Among various types of soft computing techniques, the following are the major air pollution predictive model techniques.

- Artificial Neural Networks (ANN).
- Support Vector Machines (SVM).
- Fuzzy Logic (FL).
- Hidden Markov Model (HMM).
- Genetic Algorithm.
- Particle Swarm Intelligence.
- Hybrid soft computing techniques.

A. ARTIFICIAL NEURAL NETWORK

With the pioneering work of McCulloch & Pitts, Artificial Neural Networks (ANN) has its roots in wide interdisciplinary history from the early 1940's [2]. ANN raised as a mechanism to mimic the human's brain processes [3]. ANN is an intelligent system that has the capacity to learn, memorize and create relationships among the data. ANN is made up by the simple processing units, the neurons, which are connected in a network by a large number of weighted links where the acquired knowledge is stored and over which signals or information can pass. [7]. The prediction of air quality, effectively addressed by the prediction of various air pollutants like Sulphur, Nitrogen, carbon monoxide, ozone, suspended particulate matter (SPM) by divided the data set into training, validation and verification further simulation using ANN [3].

ANN was effectively addresses the prediction of Sulphur Dioxide distribution and the future concentration in the air by modeling the Sulphur Dioxide concentration and its distribution from the air pollution station [35]

B. SUPPORT VECTOR MACHINES(SVM)

Support vector machines (SVMs, also support vector networks are supervised learning models with associated learning algorithms that analyze data and recognize patterns, used for classification and regression analysis. The basic SVM takes a set of input data and predicts, for each given input, which of two possible classes forms the

output, making it a non-probabilistic binary linear classifier [30].

The SVM model provides a promising alternative and advantageous in times series data analysis for predicting the level of air pollutants [20].

The potential of applying SVM model in ambient air pollutant prediction studied and projected as a most promising approach in prediction of PM10 pollutant[31].

C. FUZZY LOGIC

The term "fuzzy logic" was introduced with the proposal of fuzzy set theory is a form of many-valued logic, deals with reasoning that is approximate rather than fixed and exact[32].

Fuzzy Logic deals with reasoning and provides a better overview in the form of rules that defines all the conditions that are required for predicting the air pollution prediction[20].

In sugarcane processing industry, fuzzy logic can be used to classify and quantify levels of pollution as poor, ordinary, very good and excellent. The Mamdani fuzzy inference system provides the results for prediction of the air quality in and around the sugarcane industry [33].

D. HIDDEN-MARKOV MODEL(HMM)

A Hidden Markov model(HMM) is a classical approach for time series analysis and prediction.[20]. A HMM is based on the relationships between the attributes of particular data items and a data set.

Hidden Markov Model (HMM), a probabilistic function of a Markov Chain, enables the prediction of PM_{2.5}, using the meteorological measurements and its observation levels[34].

E. GENETIC ALGORITHM

Genetic Algorithm is based on Darwin's Theory [7]. It begins with arbitrary created individual population and then fitness is evaluated and parents are selected from the individuals.

Genetic Algorithms effectively addresses the change of the accumulation of the surrounding atmosphere and prediction of the thickness of the air pollutants [35].

Genetic Algorithms are effectively applied to extract the optimal feature subset of a large database containing pollutant concentration measurements, and feeds to a nearest neighbor algorithm in order to predict the daily maximum concentration for pollutants [36].

F. PARTICLE SWARM OPTIMIZATION(PSO)

Particle Swarm Intelligence is a populated search method that resembles a school of flying birds. Particles are candidate solutions to problem in hand. Each particle adjusts its flying according to its own flying experience and its companion's flying experience [11].

A PSO adopted to train multi-layer perceptron to predict air quality parameters more effectively[11].

Particle swarm optimization algorithm devised with the characters of pellucid principle and physical explication, to evaluate the grade of atmospheric pollution and multi pollutants[37].

G. HYBRID SOFT COMPUTING TECHNIQUES

The combination of more than one soft computing techniques forms Hybrid soft computing technique.

A number of hybrid soft computing techniques applied in assessment of air quality prediction efficiently.

An hybrid soft computing technique with the combination of ANN along with Fuzzy logic or with HMM and even with other soft computing techniques can be very effective for air pollution prediction and time series analysis [6].

A Particle Swarm Optimization based neural network takes a unique kind of optimization algorithm i.e. PSO algorithm to train the multi-layer perceptrons. [11]

The complex neural network with evolutionary algorithm devised ,rtNEAT (real-time Neuro-Evolution of Augmenting Topologies) , to address the air quality prediction more effectively.[6]

TABLE III
SURVEY OF AIR QUALITY FORECASTING

S.No.	Forecasting Soft-computing Techniques	References
1.	Artificial Neural Network	[1],[2],[3],[7],[16] and many more as given below in the references.
2.	Support Vector Machines	[20],[23]
3.	Fuzzy Logic	[22],[24]
4.	Hidden-Markov Model	[25],[26]
5.	Evolutionary Algorithm	[6],[9],[7]
6.	Particle-Swarm Optimization	[11]
7.	Hybrid Soft Computing Techniques	[11],[6],[14]

V. CONCLUSION

In this paper a study was carried out on various Air Pollution/quality prediction techniques with most emerging soft computing techniques. We observed the main causes for air pollution and the factors that can be responsible to minimize it. In Pollution prediction, soft computing techniques plays vital role. Further we are going to design a Hybrid soft computing technique based on ANN with Fuzzy Logic for predicting the air pollution for a particular city.

ACKNOWLEDGMENT

The authors thank the authorities and management of the University of Petroleum and Energy Studies, Dehradun, Uttarakhand, India and CSIR, NEERI, Nagpur India for the support extended to them for research in thrust areas of Computer Science.

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