Application of Artificial Intelligence in IoT based Industrial Air Pollution Prediction and Data Analysis

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Abstract - The Globe Health Organization (WHO) estimates that air pollution is directly responsible for the deaths of around 7 million people throughout the world every year. Particularly impacted are large cities, which are often referred to as "agglomerations of heavy air." However, air pollution does not recognise national or international borders, and the wind and weather are responsible for spreading air contaminants all over the globe. The material conversion processes that occur in transportation, industry, and agriculture all contribute to the emission of increasingly minute pollution particles and gases into the atmosphere. There, they combine to form an unsafe concoction of chemicals, which we then breath on a daily basis. The primary goals of this study are to (1) forecast the levels of air pollution and (2) evaluate the harm that exposure to polluted air causes to both people and structures. The Long Short-Term Memory (LSTM) network, which is a deep learning Recurrent Neural Network, is trained with the use of standard datasets (RNN). This is the first algorithm that, because to its internal memory, can remember its input, and as a result, it is ideal for solving issues in machine learning that include sequential data. The implementation is considered to be in the area of time series data prediction, which is something that LSTM is capable of doing with a high degree of accuracy.

Keywords: air pollution, LSTM, RNN, forecast

I. INTRODUCTION

Nitrogen makes up 78 percent of the composition of clean air, while oxygen accounts for 21 percent. In addition to these, there are also additional trace gases, such as argon (0.9%) and carbon dioxide (0.04%) [1]. Our lungs get the ideal amount of oxygen delivery from this inoffensive, odourless, and colourless gas combination. The divergence of the air's composition from its natural values as a result of the release of potential pollutants is what is referred to as air pollution. On the other hand, there is no place on Earth where one may get genuine "original air." The reason for this is that human activity has always contributed to the pollution of the atmosphere. Because of this, we are forced to accept polluted air as a natural state of things in the contemporary world, and this is true both outdoors and inside of buildings [2].

Therefore, the issue that has to be answered is not whether or not the air is contaminated; rather, the one that needs to be answered is what amount of air pollution is tolerable without having long-term effects for both the environment and human health. The majority of pollutant particles in the air come from human activities [3]. Incomplete material conversion processes, such as combustion, produce a wide variety of chemical, biological, and physical pollutants, which are then discharged into the atmosphere. These compounds that are released are considered main pollutants. A chemical reaction takes place in the air as a result of the interaction of wind, heat, and radiation from the sun [4]. The fundamental constituents combine and exchange electrons with one another. This results in the production of secondary air pollutants such as ozone and fine particles. Because of this, the levels of ozone and particulate matter pollution in cities, especially during the summer months, reach dangerously high levels. This concoction of hazardous chemicals, which is formed when all of these air pollutants are combined and seen as a whole, is something that we unavoidably breathe in. Both our health and the ecosystem will be substantially impacted as a result of this [5].

There are significant regional variations in the levels of air pollution. There are a variety of forms, and the pollution is often categorised according to the groups that cause it. Because of this, the WHO makes a distinction between the types of air pollution that are found "within rooms" (from houses) and "outside" (from industry, transport or agriculture). These distinct industries do not contribute to air pollution in the same manner. Each category is primarily responsible for the emission of a particular pollutant. The industrial sector is the primary contributor of particulate matter, sulphur oxides, and carbon dioxide. Natural processes are another potential source of air pollution. For example, owing to volcanism, fires, pollen count or dust storms. On the other hand, these factors as a whole are far less relevant, and as a result, they may be ignored to a big extent [6].

Researchers from every corner of the globe have come to the same conclusion: air pollution is a key contributor to the deterioration of health and the spread of illness. The World Health Organization (WHO) estimates that air pollution is responsible for around 7 million fatalities per year [7]. The load is especially heavy in economically developing nations

like China and India, for example. There are still conditions that can be found in many cities that are comparable to those that existed in Europe shortly after the beginning of the industrial revolution.

Life expectancy is three years lower than the global average in New Delhi, India, which is the capital of the country with the greatest level of air pollution. The levels of fine dust pollution there are several times higher than the limit standards set by Europe. There are moments in Beijing when things doesn't seem to have changed all that much. For instance, during the winter of 2016, the Chinese city was engulfed in a thick haze of pollution for the whole of one month. However, there are other times when the air is consistently dense throughout Europe, such as when you're in Paris or the region around Stuttgart [8].

In many cases, the secondary pollutants are significantly more hazardous than the primary pollutants that they originated from [9]. The respiratory tract may get irritated by ozone, which becomes hazardous at greater doses. There is a strong correlation between cancer and particulate matter. The reason for this is because the particles might occasionally be so minute that they pass through the alveoli and into the circulation. They get into the cells of our bodies this way, and once there, they may set off responses that we have no control over.

On the other hand, coarse pollutant particles such as smoke or soot will settle in the lungs. Similar to the effects of smoking cigarettes over a long period of time, prolonged exposure may result in black discoloration, damage to tissue, and eventually lung cancer [10].

Pollution in the air has a significant influence not only on the climate but also on the ecosystem. For instance, an excessive amount of nitrogen oxides and ammonia would result in the eutrophication of soils and water, which will disrupt the natural ecological equilibrium. In addition, polluted air has a natural influence on the flora and wildlife, which, just like people, are dependent on oxygen-rich air. In addition, some contaminants in the air, such as carbon dioxide and methane, are contributing factors in the shift in climate [11].

II. LITERATURE REVIEW

Lifeng Wu [12]: The Beijing-Tianjin-Hebei area is dealing with a very serious issue with air pollution. This is done in order to get an idea of the upcoming drift of air superiority. In this region, there will be an increase in the amount of 8-h and 24-h O3 in addition to a reduction in the PM2.5 and SO2 concentrations that have converged. The number of PM10 clusters and the concentration of NO2 both go down in the region bordering the Taihang Mountains, whereas they go up in the Northern district. The concentration of PM10 will result in a decrease in the amount of NO2 that is produced within the area. Our findings have the potential to be misused in uncomplicated ways inside fundamental leadership structures for air superiority management.

Rossella Arcucci [13]: To have a better understanding of the intricate air flows and pollution delivery on the scales of individual buildings, city blocks, and whole cities The use of numerical reproductions as a kind of predictive technology is widespread. We advocate a Variational Data Assimilation (VarDA) adaption, which is a method that gathers data from sensors in a manner that is not constrained by any model that has restricted components, constrained supplies, or liquid elements. Fluidity in order to enhance forecasting of wind streams and the transport of contaminants. VarDA is dependent on the minimization of capacity, which evaluates inconsistency among mathematical outcomes and perceptions. This is done under the assumption that both conjecture and perceptions, which are two different sources of data, contain errors that can be adequately portrayed by error covariance frameworks. The findings of the trial are presented assuming watched values supplied by sensors from sites that are mostly positioned on the highest points of buildings.

Yu Pengfei1, He Juanjuan1, Liu Xiaoming1, and Zhang Kai1,2(B) [14]: In this study, a model that uses a deep neural network is suggested as a means of predicting manufacturing-related air pollution such as PM2.5 and PM10. This allows for the network's production of hidden layer neurons to be constructed. When information such as CO, NO2, O3, and SO2 that are produced by mechanical and industrial facilities is collected, the Twelve air toxin indicators are produced.

Temesegan Walelign Ayele [15]: The Internet of Things (IoT) is a concept that refers to a system that consistently figures devices. This concept does not take into account human to human communication or communication between humans and appliances. During the course of this study, a framework for IoT-based air contagion observation and forecasting will be provided. In addition to measuring air quality, this system may also be used to investigate local air quality and check for the presence of airborne toxins in a particular region.

Congcong Wen [16]: The spatiotemporal convolutional long transient memory neural system expanded (C-LSTME) model for predicting air quality will be projected throughout the present experiment. In order to include both the spatiality and the fleetingness of the information, the model incorporated into its structure the actual air poison convergence of the station that was being used at the time, as well as that of the flexible k-closest nearby stations. In order to improve reproduction forecast performance, it is necessary to first extract high-level spatiotemporal highlights through the combination of a convolutional neural network (CNN) and a long transient memory neural arrange (LSTM-NN), and then additionally incorporate both meteorological and airborne data.

Athira..V [17]: Conventional methods of forecasting air quality depend on numerical information and demand a growing amount of processing power for the calculation of poison fixation, both of which result in an output that is undesirable. In order to solve this problem, we used a model that is often used for deep learning. In order to make sense of

the optimal design, we performed a comprehensive evaluation of a wide variety of RNN models and their variations, each with its own topologies and model parameters. By varying the learning rate between the ranges of [0.01] and [0.5], each test was brought closer to 1000 years of age. It is clear from the analysis that all three models delivered a performance that was satisfactory in relation to the expectations.

Z. Ghaemi & A. Alimohammadi & M. Farnaghi [18]: Traditional methods, such as the support vectormachine (SVM) or artificial neural networks (ANN), have a few shortcomings when an enormous amount of flowing data has to be analysed for the purpose of urban air pollution forecasting. The goal of overcoming the limitations imposed by the conventional approaches and enhancing the presentation of the anticipated levels of urban air pollution in Tehran. Continuous updates of contamination fixation and climatic information in addition to geological characteristics are being added to the internet-based gauging framework that has been developed. The findings demonstrate that the online approach achieves an amazing boost in speed while maintaining the SVM classifier's accuracy.

Qunli Wu a,b, Huaxing [19]: The Lin Least squares support vector machine (LSSVM). Through the process of combining the predicted projections of each subseries, one may arrive at a definite assessment of the result of AQI. The projected optimum half breed model is shown to have enhanced proper speed of gauging AQI modules, as shown by complete correlations via a lot of assessment lists. This model also totally captures the features of the initial AQI arrangement.

III. RECURRENT NEURAL NETWORK (RNN)

Because they are composed of cycles that can store the information, recurrent neural networks are capable of finding a solution to the problem of time series.

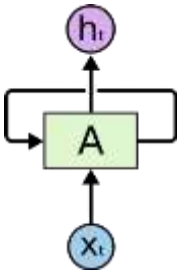


Fig 1: Cycles in RNN

Because RNNs include cycles, they give off an air of being somewhat enigmatic. However, if you examine them in further detail, it becomes obvious that they are not dissimilar in any way to a straightforward neural network. One way to understand an RNN is to see it as numerous copies of the same network, with each copy delivering a message to a successor in the chain. Consider the following events that take place whenever a cycle is scanned:

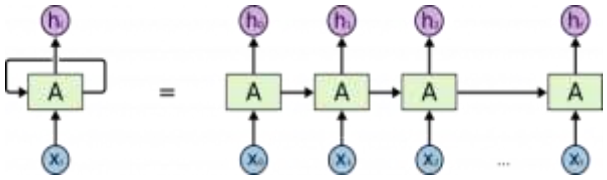


Fig 2: Cycle scan in RNN

The RNN's scanned structure reveals that recurring neural networks have tight ties to sequences and lists. This is evident in the structure of the RNN. When dealing with information of this kind, the design of a neural network should look something like this.

They are without a doubt put to extensive use in today's society! In recent years, RNNs have had an astonishing amount of success when used in research fields such as voice recognition, linguistic modelling, translation, picture description, and many more. The list might go on forever. They are a specialised kind of recurrent neural networks, and they tackle individual problems significantly more quickly and effectively than conventional approaches. There is a correlation between the use of LSTM networks and all notable outcomes based on RNN.

The problem of long-term relationships

The recurrent neural network makes use of the information that was collected in the past in order to solve the upcoming problems. For instance, the subsequent video fragments might be examined on the basis of the ones that were obtained in the past.

In order to complete a job, you may just need the most recent piece of information. For instance, a language model may be developed that looks at the words that came before it and attempts to guess what word will come after it. There is no need for any extra information in order to forecast the last word of the sentence "clouds in the sky"; it is obvious that the next word will be "heaven." The RNN will take care of the job if there is not a significant time lapse between the prior information and the point when it is required. RNN is only able to do this duty effectively when there is a very short gap between the most recent information and the location at which it is required.

However, there are situations when further context is required. Let us take a look at the following paragraph and try to guess what the last word will be: "I grew raised in Germany... I speak German well." It is abundantly evident from the terms that came before the following word that it is most likely the name of the language. In order to properly address the language, it is necessary to take into consideration the fact that Germany is involved. As time goes on, the gap that exists between the moment at which certain knowledge is needed and the point at which it is required becomes wider.

When the distance between the nodes in the RNN grows, this results in the loss of the link between the information.

In principle, RNN is capable of dealing with "long-term dependencies." The researcher might take their time to meticulously configure the settings of the network in order to find a solution to this issue. Regrettably, RNN cannot fix this issue in reality because of how it works.

LSTM networks

Under the acronym LSTM, which stands for "long short-term memory," a recurrent neural network is a sort of network that can learn long-term dependencies. Hochreiter and Schmidhuber were the ones who first used LSTM in their study; other researchers went on to refine and popularise the method. It is still commonly utilised despite the fact that it is capable of effectively completing numerous jobs. The Long Short-Term Memory (LSTM) algorithm was designed with the intention of resolving issues associated with long-term reliance. Since information storage for extended periods of time is one of their primary functions, one might argue that they seldom ever need instruction.

The structure of a recurrent neural network always takes the form of a series of modules that are used repeatedly in the network. This recurrent module in a normal RNN will often have a straightforward structure, such as a **Tanh** layer, for example.

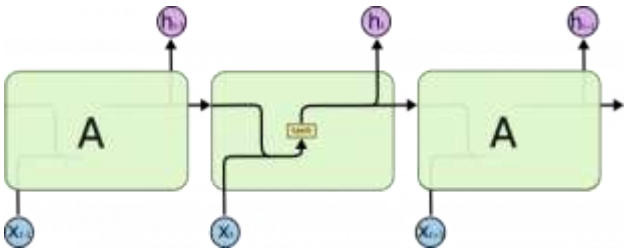


Fig 3: The recurring module of the standard RNN contains one layer

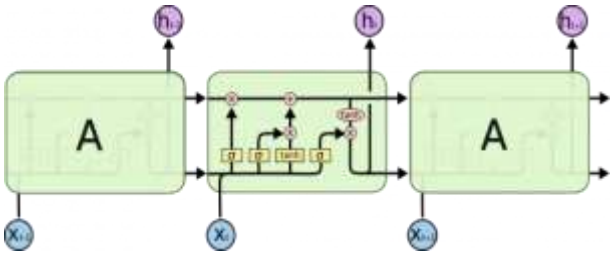


Fig 4: The recurring LSTM module contains four interacting layers

At this point, the specifics are irrelevant to the discussion. Let's have a look at some of the terminology that will be discussed later.

Fig 5: Notations

Each line represents a different vector. Operations that are performed on a point-by-point basis, such as the summation of vectors, are represented by a pink circle. The layers of a neural network are shown by the yellow cells. The line connection represents the union of many vectors, and the sign of the fork indicates that a copy of the vector is being made with the intention of storing it in multiple locations.

How the LSTM network works

The cell state is the most important idea to grasp when working with LSTM; it is represented by the horizontal line that traverses the top of the figure.

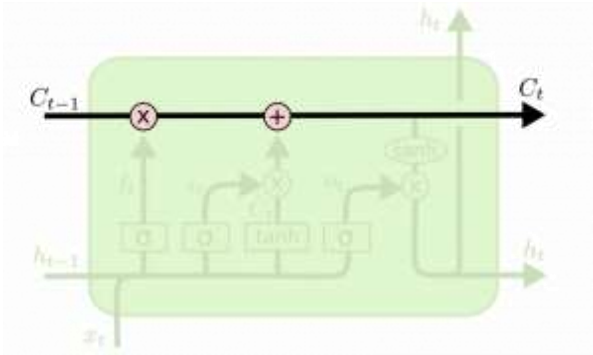


Fig 6: LTSM gate

Whether LSTM reduces or increases the total quantity of information stored in a cell state is determined on the requirements of the task. In order to do this, structures that have undergone a painstaking adjustment process and are also known as gates are used.

A "gate" is just a structure that determines whether or not information may pass through it. A sigmoid layer of a neural network and a point-by-point multiplication operation are the two most significant components of gates. Gates are used in logic circuits. At the point where the sigmoid layer ends, a number between 0 and 1 is produced as an output. This number is used to calculate the percentage of each information unit that is to be sent on to the next layer. The number "0" indicates that no data should be sent through, whereas the value "1" indicates that all data should be passed through.

In LSTM, there is a difference made between three gates for testing the cell state, all of which are investigated in further depth in the following paragraphs.

Loss layer

The very first thing that must be done is to determine which information is discarded from the current state of the cell. A sigmoid layer known as the "forget gate layer" is responsible for making this determination. She reads the h and x parameters and then returns a number between 0 and 1 for each of the values in the cell state C on. The value 1 indicates "fully save," whereas the value 0 indicates "totally delete."

Let's take a second look at the example we used before of the language model. At this point, an effort is made to guess the following word based on all of the words that came before it. In a task like this one, the cell state stores the subject's gender so that the appropriate pronouns may be used. When addressing the new topic, it is necessary to disregard the gender of the earlier subject.

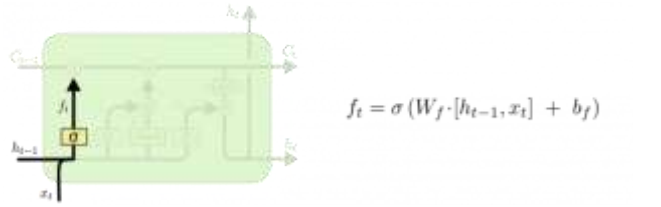


Fig 7: Loss layer

Storage layer

The next step is to determine which of the newly acquired pieces of information will be saved in the cell's state. This procedure is broken down into two distinct phases. The sigmoid layer, also known as the "layer of the input gate," is the one that makes the first determination on whether values need an update. The **Tanh** layer will then generate the vector of fresh values **C**, which will be added to the cell's current state. The next step is to link these two data in order to update the status.

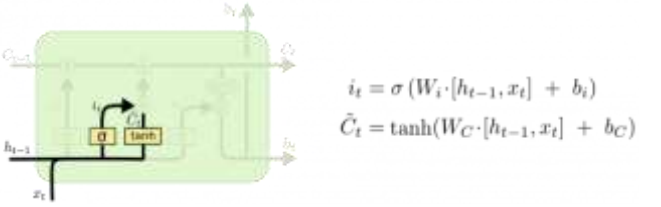


Fig 8: Storage layer

New condition

The prior cell state has been brought up to date with the new state that **C** will obtain. Following the procedure of selecting the update method, the update procedure itself is then executed.

To begin, the previous state is multiplied by **f**, which results in the knowledge that was previously forgotten being lost. Then i multiplied by C is added. These are more candidates for the value. After then, they are scaled in a manner determined by the manner in which each state value was altered.

In the case of the language model, the information that was previously provided on the gender of the old topic is omitted, and it is replaced with new information.

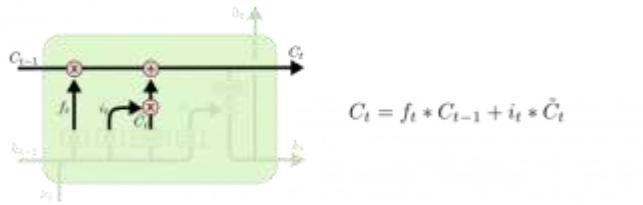


Fig 9: New state update

At this point, it is necessary to decide on what kind of items should be bought at the exit. The filtered cell state is the end product of this process. The sigmoid layer is the first one to be activated, and its function is to determine which aspects of the cell state are to be output. The state of the cell is then multiplied by the signal that is produced by the sigmoid gate after it has been run through the tanh function (which places all values in the range [-1, 1]).

Due to the fact that the network only interacted with the subject, it is able to produce the information that pertains to the verb for the language model. For instance, the network will output information about the subject's number (whether it be solitary or plural) so that the verb may be appropriately conjugated.

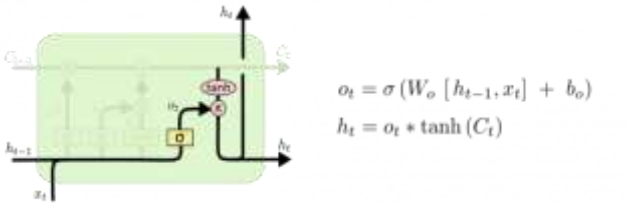


Fig10: Final Decision layer

IV. EXPERIMENTAL RESULTS

The research is conducted using the data on air pollution that was supplied by the pollution control board in India. The information on the various pollutants is gathered over the course of three years. For the purpose of predictive analysis, the LSM approach that was presented may be applied. The following is a list of contaminants that are currently being researched:

A. Particulate Matter

The majority of fine dust is produced as a result of human activity. On the other hand, it could also have a natural origin (for example as a result of soil erosion). In conurbations, the primary contributor to air pollution caused by dust is road traffic. Fine dust is released into the atmosphere not only by engines, and more specifically by diesel engines, but also by the abrasion of brakes and tyres, as well as by the whirling of dust that is kicked up from the road surface. Agriculture is also a significant contributor, since it produces emissions of gaseous precursors that lead to the subsequent generation of fine dust. In particular, ammonia emissions from animal husbandry are a major contributor.

Health risks

In humans, particles with a size of PM_{10} are able to enter the nasal cavity, particles with a size of $PM_{2.5}$ are able to enter the bronchi and alveoli, and ultrafine particles are able to enter the lung tissue and even the bloodstream. The effects of fine dust on one's health can vary depending on the particle's size as well as the depth to which it penetrates.

B. SO2

The oxidation of the sulphur that is naturally present in fossil fuels like coal and oil is the primary mechanism by which sulphur dioxide is produced. This process takes place during the burning of these fuels.

Health risks

The mucous membranes become irritated when sulphur dioxide is present, which may also cause irritation to the eyes and respiratory system. Because the concentrations of SO_2 throughout the country are now so far below the relevant limit values for the protection of human health, it is no longer necessary to be concerned about the potential adverse effects of SO_2 on people's health in Germany.

Effects on ecosystems

After being deposited in ecosystems, sulphur dioxide has the potential to harm plants and create acidification of both the soil and the water. Since the early 1990s, there has been a significant reduction in sulphur emissions; as a result, nitrogen imports are primarily responsible for acidification. These days, limit values for the concentration of SO_2 are very well observed everywhere.

Limits

Sulfur dioxide limitations have been in effect throughout Europe ever since January 1, 2005, and their primary purpose is to safeguard human health. The one-hour limit is set at 350 $\mu g / m^3$, and the threshold may only be crossed a maximum of 24 times per year. The daily limit of 125 $\mu g / m^3$ must not be exceeded more than three times over the course of a calendar year. 20 micrograms per cubic metre is the essential amount that must be maintained as the annual and winter mean from October to March.

C. NO2

Nitrogen oxides are part of a class of substances known as reactive nitrogen compounds, which are known to have a range of deleterious impacts on the surrounding environment. Nitrogen oxides, in conjunction with volatile hydrocarbons, are the primary contributors to ozone production throughout the summer. Nitrogen oxides can contribute to fine dust pollution.

Issuers

Nitrogen oxides are the byproducts of combustion processes that result from unintended side reactions. Internal combustion engines and combustion facilities for coal, oil, gas, wood, and waste are the primary contributors of nitrogen oxides to the atmosphere. Road traffic is the single most important contributor to NO_x levels seen in metropolitan areas.

Health risks

Nitrogen dioxide concentrations that are naturally prevalent in the environment pose an issue for people with asthma in particular. These concentrations may cause bronchial constriction, also known as bronchoconstriction, which can be made worse by the impacts of allergens, for instance.

Effects on ecosystems

Nitrogen oxides, particularly nitrogen dioxide, have the potential to cause harm to plants. This damage may include the necrosis of the leaves, which is a yellowing of the leaves, as well as premature ageing and reduced development. In addition to this, nitrogen dioxide is a factor in the overfertilization and acidification of soils, as well as, to a lesser degree, the acidity of water.

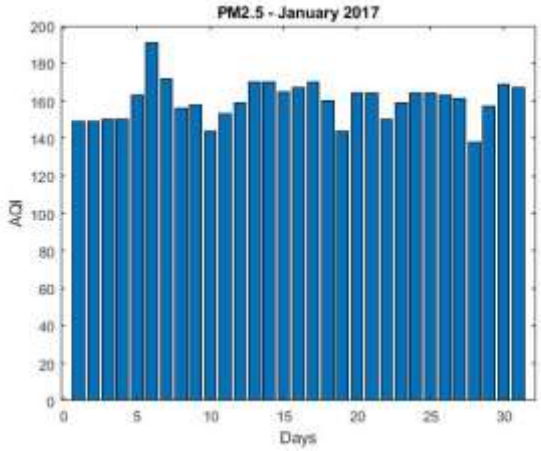
Limits

Nitrogen dioxide has a one-hour limit in Europe of 200 micrograms per cubic metre, which must not be exceeded more than 18 times in a single calendar year. This restriction was established to safeguard the health of humans. The yearly limit is 40 micrograms per cubic metre. As a precautionary measure for the plant life, the annual mean NO x concentration has been set at the crucial threshold of 30 micrograms per cubic metre.

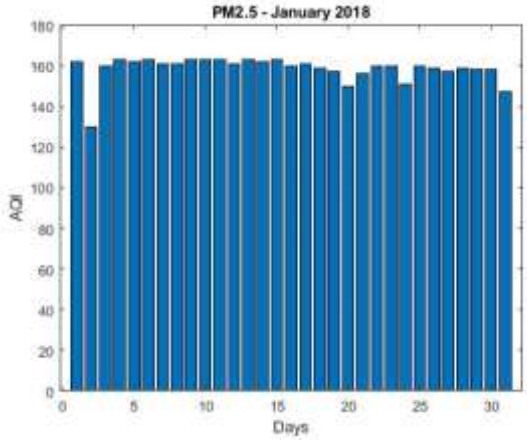
Air Quality Index

The air quality index, often known as AQI, is an aggregated indicator that is created by combining individual pollutant readings for the air pollutants carbon monoxide (CO), ozone (O 3), nitrogen dioxide (NO2), and particulate matter fraction (PM 10). When calculating the AQI, special attention is paid to the short-term health implications of each of the various air contaminants. When determining the index classes for each of the five air contaminants, epidemiological and toxicological research are taken into consideration.

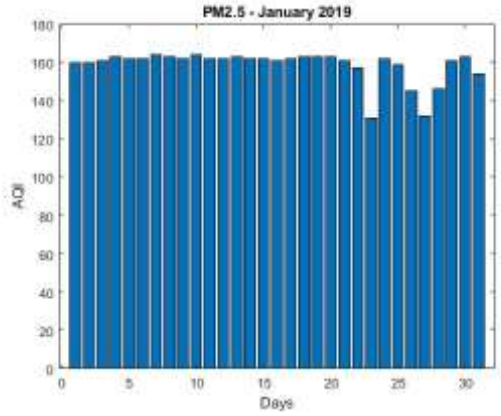
The following graphs illustrate how the air quality index in Hyderabad changed during the course of the year.



a. January 2017

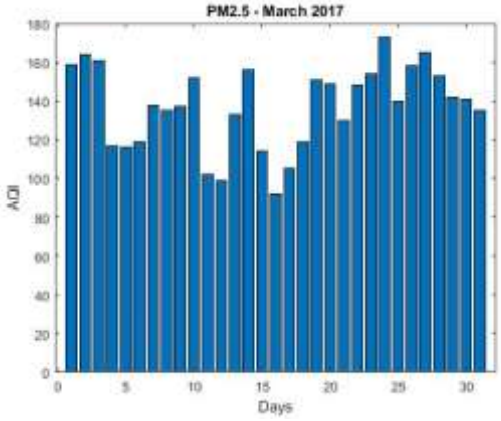


b. January 2018

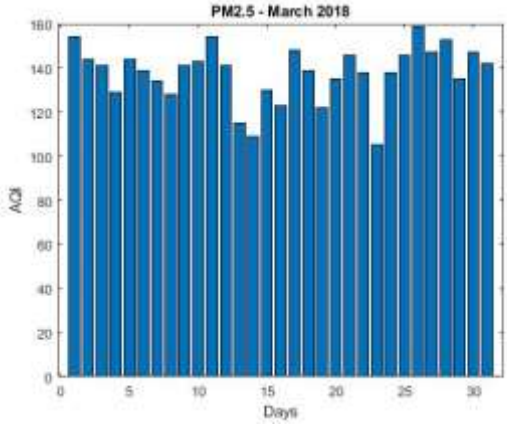


c. January 2019

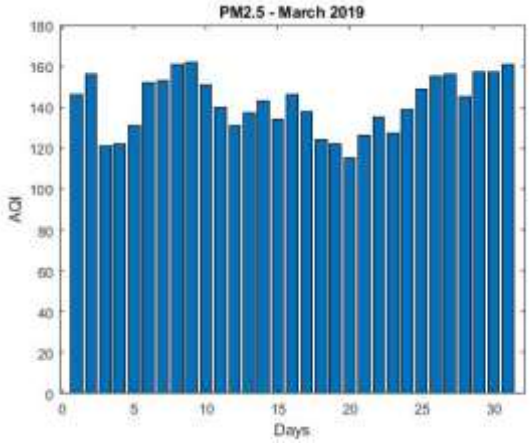
Fig 11: PM2.5 pollutant QI January



a. March 2017

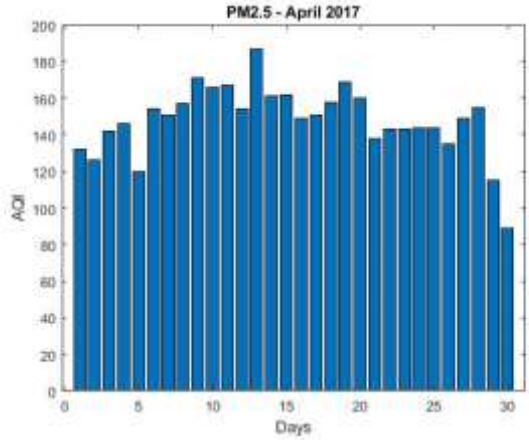


b. March 2018

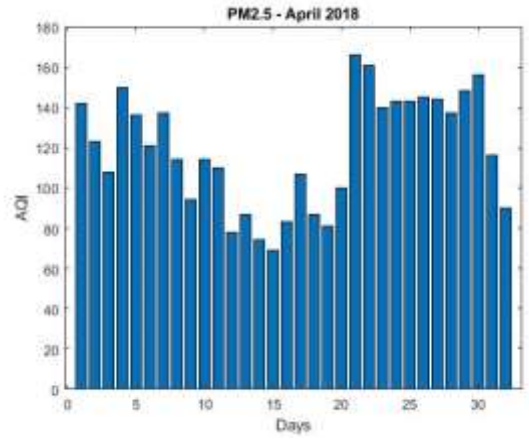


c. March 2019

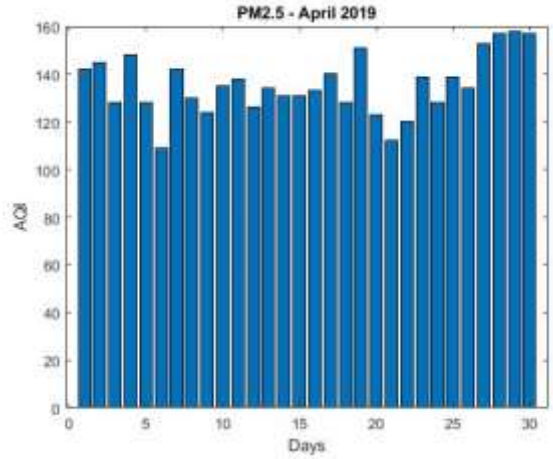
Fig 12: PM2.5 pollutant QI – March



a. April 2017

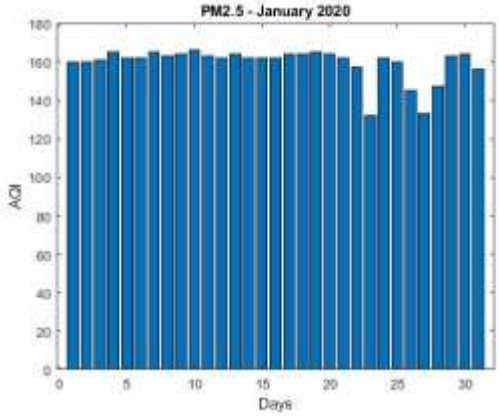


b. April 2018

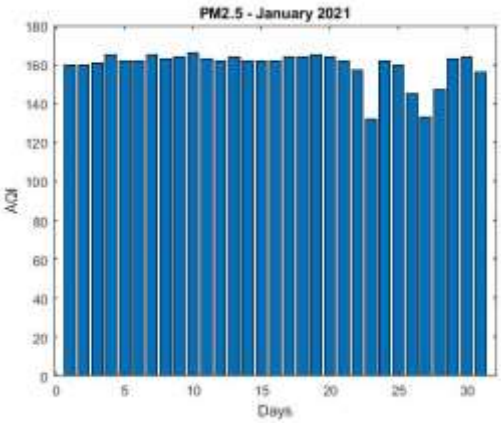


c. April 2019

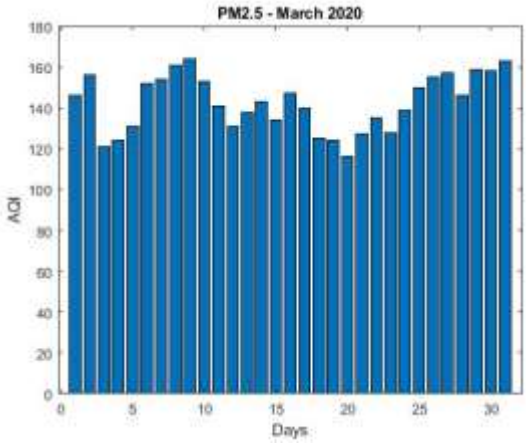
Fig 13: PM2.5 pollutant QI – April



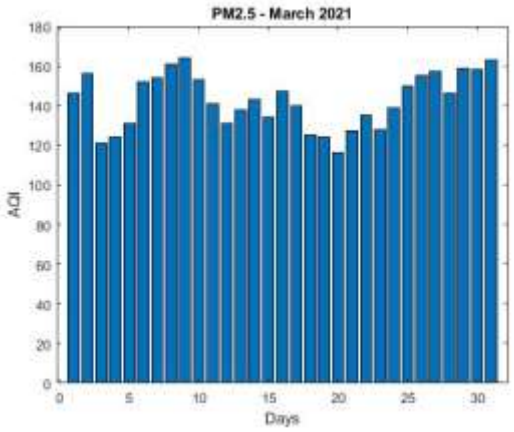
a. January 2020



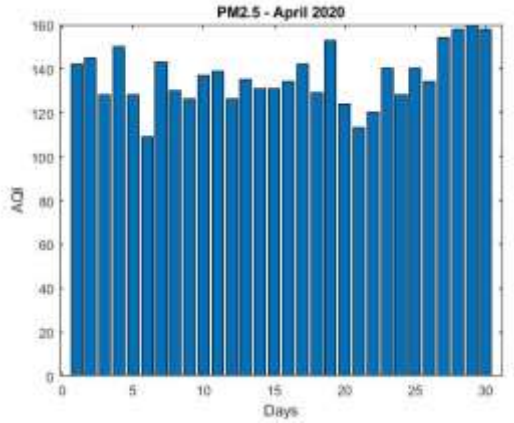
b. January 20201



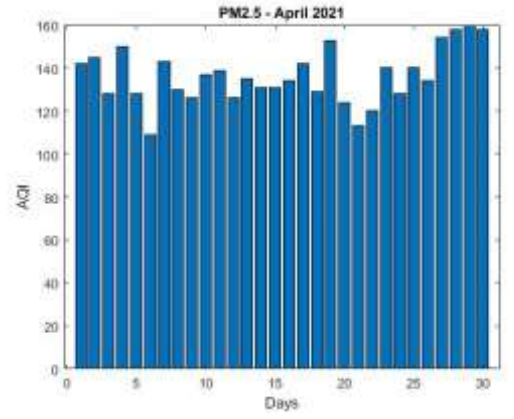
c. March 2020



d. March 2021



e. April 2020



f. April 2021

Fig 14: Predicted PM2.5 values

V. CONCLUSION

Obviously, the way in which we treat our air will have repercussions of some kind. People and the environment in a great number of developing nations are especially vulnerable to the effects of smog, despite the fact that air pollution in Germany is typically on the decrease. The environmental crisis, which is virtually entirely brought on by human activity, finally brings about negative effects not just for the ecosystem but also for our own health.

Consequences for our health

The impact of air pollution on human health should not be minimised, despite the fact that the contamination in the air is difficult to detect. There is a direct correlation between the amount of pollution in a region and the severity of the health hazards associated with being exposed to that pollution.

- **Respiratory diseases:** The bronchi are unaffected by fine dust particles (PM2.5), which have a diameter of 0.1 to 2.5 microns and may go via the nasal cavity, the throat, and the trachea. As a consequence, the individual's lung function may decrease, and they may even have an asthma attack or bronchitis.
- **Cardiovascular diseases:** The diameter of ultrafine dust particles is less than 100 nanometers, making them one thousand times smaller than the diameter of a human hair. Ultrafine dust particles may be found in a variety of environments. 4) They are not capable of being pre-filtered by the nose, throat, or windpipe, and are thus able to enter the bloodstream without causing any harm when exposed to precipitation. The repercussions may even lead to a heart attack in certain cases.
- **Higher mortality:** It has previously been shown via research that being exposed to high levels of air pollution lowers a person's life expectancy.

These negative effects of breathing in polluted air are good reasons to work to reduce overall levels of air pollution and your own personal contributions to the problem.

Impacts on the environment and climate

Unfortunately, the effects of pollution on our natural environment are significant and detrimental. For instance, these make a significant contribution to climate change and are the reason why we, as a society, are currently required to do everything in our power to halt climate change.

These negative effects on the environment can be attributed to polluted air:

- **Agriculture:** The release of nitrogen oxides into the atmosphere can have a detrimental effect on the leaf development of plants.
- **Ecosystems:** The presence of sulphur and nitrogen oxides is a major danger to the health of our ecosystems. The acidification and overfertilization of delicate ecosystems is a risk posed by pollution in the air. The environment often has the unintended effect of causing harm to trees.
- **Climate:** The greenhouse effect and the progression of climate change are both directly influenced by fine dust and soot. In addition, the increasing frequency of acid rain poses a risk to the carbon dioxide-bound plant life.

There is a long rat tail hanging behind these consequences, which is connected to other problems for humans, animals, and nature.

Consequences for business and society

The following are some of the repercussions of air pollution that may be seen from an economic point of view:

- **Harvest failures:** A failed harvest is a logical result of the unclean air, which has a detrimental impact on the development of plants as well as the fertility of the soil.
- **Damage to buildings:** The burning of coal and heating oil both result in the production of sulphur dioxide, which is a carcinogenic gas. The subsequent acid rain is destructive to buildings and therefore results in significant additional costs for restoration.
- **Health costs:** Not only are there enormous expenditures for the state, but there are also significant prices for each one of us individuals individually. Because of the terrible frequency with which respiratory and cardiovascular problems develop as a direct result of exposure to air pollution. As a direct consequence of this, health care expenses have increased.

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