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Classification of air pollutants caused by e-waste and health risk evaluation

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ABSTRACT

Air Pollution is one of the serious problems in society, and it is hazardous for human health. E-waste disposal is the primary reason for air pollution. When the pollutant present in the air crosses the limit, it may lead to death in human. This paper focuses on the analysis of a range of air pollutants and the database is attained from the Central Pollution Control Board. In this paper, we used decision tree classifier as well as naive bayes classifier for predicting health risk due to air pollutants and the classification is done based on air quality index. The result shows that the decision tree produces an accuracy of 97.2% and naive bayes classifier have an accuracy of about 97.9%, which is more than that of the decision tree.

Key words : *Air pollution, Air quality index, E-waste, Decision tree, Naive bayes classifier*

Introduction

Electrical and Electronic Equipment hang on electric currents to work. In recent years, the impact on the environment gest increasing due to the change in our lifestyle and developing technology leads to an increase in e-waste. Some parts of the e-waste are recyclable because of the material decomposition (Gaidajis *et al.*, 2010). E-waste is different from urban as well as industrial waste. The e-waste can produce ill-effects, and so it can be recycled carefully to protect living creatures. India leads the fifth largest e-waste producer in the globe, and it roughly produces 2 million tons of e-waste every year (Joon, *et al.*, 2017). The amount of e-waste generated by each state in India varies. It is explained in Figure 1.

The process of inappropriate recycling and discarding of e-waste leads to environmental effects. Air pollution is a big problem in India and e-waste is avital reason. While recycling process, e-waste discharges dust particles into the air. Plastic e-waste products when burnt produces a large amount of fine particles, and it can travel thousands of miles (Wilson, 2019).

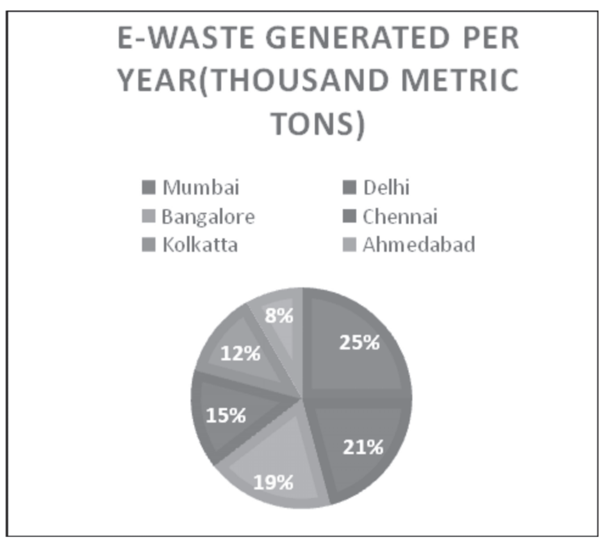

Fig. 1. Generating e-waste in India

The e-waste sectors are overgrowing rapidly in developing countries due to less labour cost and weak law formulation. It may affect human health, and it can lead to lung damage due to particulate matter (PM). According to The Times of India, India will produce 5.2 MMT per year by 2020 due to economic growth and consumption patterns change (Shenoy, 2019).

E-waste has two significant substances: They are Hazardous substances and non-hazardous substances, which creates an impact on the environment. According to India Today, people living in Delhi is undergoing severe breathing problems (Nikhil Rampal, 2019). According to the Air Quality Index, 14 cities in India have severe air pollution, and the condition is critical according to CPCB standards, and it is shown in Table 1.

Air pollution is a diverse fusion of gases and particles coming from a various stationary and mobile sources discharged within the atmosphere. Children are affected more due to air pollution due to their developing bodies and inhaling high dose of pollution when compared with adults. Nitrogen oxides (NOx) and particulate matter (PM) obtain more attention when compared with ozone (O3) and sulphur dioxide (SO_2). There is a corroboration available for the harmful effect of air pollution on cardiovascular events. There are three important hypotheses projected by air pollution when sniff into the pulmonary system produce cardiovascular effects: 1) particle causing negative reaction in the lungs; 2) pollutant damaging sensory nerves and 3) direct entry of pollutants into the pulmonary circulation. It is shown in Figure 2.

Out of all the pollutants, PM 2.5 crosses the standards, followed by PM10, NO2, CO, and Ozone. SO2 complies with the nationalized standards. Source of every pollutant differ by contributions from various sources. The primary source of air pollution are exhaust from vehicle, power generation, small scale industries, dust due to vehicle movement, burning waste in open areas. Seasonal impact from dust storms, forest fires, sea salt near coastal areas.

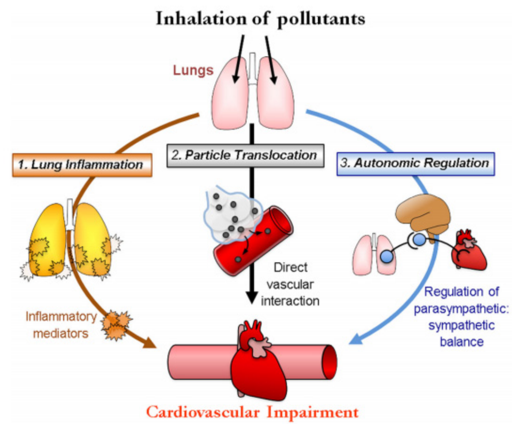

Fig. 2. Pollutants affecting lungs

India is the third-largest country which emits greenhouse gases after China and the United States. The rigorousness of air pollution is that the life span of Indians reduces on an average of 3.4 years among the residentaries of Delhi. According to the Central Pollution Control Board, there are six types of air pollutants, and they are Nitrogen dioxide, Sulphur dioxide, and Carbon monoxide, Ozone, PM2.5 and PM10. The Air Quality Monitoring Station monitors the air pollutant at a range of time occurrence. The device is built up with various gas sensors and dust particles sensors ("Air Quality Monitoring Station"

Table 1. AQI Ranking

Rank	City	AQI	Condition	State
1	Jind	448	Severe	Haryana
2	Baghpat	440	Severe	Uttar Pradesh
3	Ghazidabad	440	Severe	Uttar Pradesh
4	Hapur	436	Severe	Uttar Pradesh
5	Lucknow	435	Severe	Uttar Pradesh
6	Moradabad	434	Severe	Uttar Pradesh
7	Noida	430	Severe	Uttar Pradesh
8	Greater-Noida	428	Severe	Uttar Pradesh
9	Kanpur	427	Severe	Uttar Pradesh
10	Sirsa	426	Severe	Uttar Pradesh
14	Delhi	407	Severe	Delhi

2019). There are 573 monitoring stations in 26 states of the country. The primary goal of air quality monitoring network is to find the areas where pollutant level violates ambient air quality standard. Table 2 shows various pollutants and human health effects.

Particulate Matter (PM) is a combination of solid and liquid particles which are organic and inorganic in the air which are harmful to health. Particles do not have any shape, but they are expressed in sphere form. PM is found near the surface, and the formation mechanism differs. PM simulation is one of the challenging tasks for environmental protection (Liang, 2013). Primary Particulate Matter is discharged from the ground into the air, and the secondary Particulate Matter is produced in the air. PM particle get emitted into the air due to human actions. With PM control techniques, a coarse PM can be reduced. The understanding of chemical combination which produces PM helps to decrease air contamination. Figure 3 shows the graphical representation of the contribution of sources to PM2.5 and PM10.

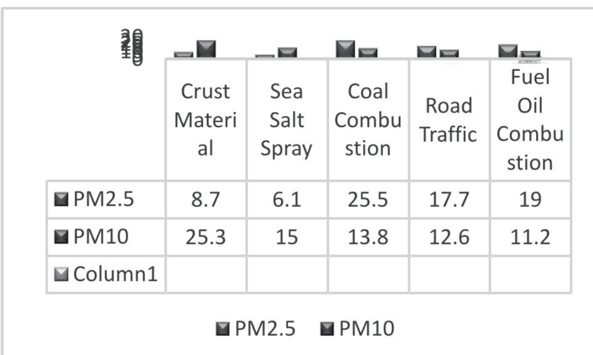

Fig. 3. Graphical Representations of Particulate Matter

Chi-Square

The Chi-Square is used to find the relationship between categorical variables using a bivariate table and follows chi-square distribution. It is used to find the difference between observed data and expected data. Chi-square distribution is a cumulative probability distribution and contributes the chance of each probable value that occurs. Distributions give the chance of a random variable being smaller than or equivalent to a specific value. The computation probabilities are equal to the total area under the curve.

The degree of freedom is needed for performing the chi-square test. It is found by subtracting one from the number of categories in the data. It is used when there is a single population which has categorical variables. Chi-Square test is used to find the association between two groups by calculating hypothesis and also to find out how observed data fits with expected data. The particulate matter of contribution of sources called as observed value is shown in Table 3.

The expected value of particulate matter is the expected data in the contingency table if the variables are statistically independent for different sources is calculated as shown below:

$$Expected\ value(PM2.5, crust) = \frac{(PM2.5)(crust)}{Total}$$

$$= \frac{81X39}{161}$$

$$Expected\ value(PM10, crust) = \frac{(PM10)(crust)}{Total}$$

$$= \frac{80X39}{161}$$

= 19.38

Table 2. Pollutants and Human Health Effects

Pollutant Name	Effects on Humans
SO_2	Bronchitis, Heart tissues, Respiratory illness and asthma.
NO_2	Leads to acid rain and corrodes metals due to acid formation.
$PM_{2.5}$	Cardiovascular disease, respiratory problems.
PM_{10}	Cardiovascular disease, respiratory problems.

Table 3. Observed Value of PM for all sources

	Crust Material	Sea Salt Spray	Coal Combustion	Road Traffic	Fuel Oil Combustion	Row Total
$PM_{2.5}$	13	6	26	17	19	81
PM_{10}	26	15	14	13	12	80
Column Total	39	21	40	30	31	161

The expected value of particulate matter for all sources are calculated and shown in Table 4.

The next step is to calculate the degree of freedom which indicates the maximum number of independent variables. It is calculated using the formula: (row-1) * (column-1)

=(5-1)*(2-1) = 4

The null hypothesis indicates there is no relationship between categorical variables and they are independent. Bivariate table shows the distribution of two categorical variables and the intersection of the categories of the variable appears in the cells of the Table (Cochran, 1952). The Chi-Square test helps to compare the statistical value with the critical value, and it is expressed as:

$$x^2 = \frac{(observed\ data - expected\ data)^2}{expected\ data}$$

The Chi-Square value is calculated for the particulate matter, and it is shown in Table 5. When the value of chi-square is low, and the chi-square statistics value is greater than 10, there is a high correlation between two sets of data. The p-value is indicated against the null hypothesis, and it is calculated when running two categories.

It is observed that the chi-square statistic value is 13.8988. The p-value is 0.007625 and the significance value is less than 0.05. Air pollution creates a significant impact on human health in China and an average of 1.3 billion people re-exposed to PM every year. The most common disease due to air pollution is a chronic respiratory disease, cardiovascular disease, and gastrointestinal disease. Increase in air pollution in developing countries lead to pulmonary disease, hypoxemia, COPD etc. (Lu *et al.*, 2015). The main health problems due to air pollution are shown in Figure 4.

PM can increase the mortality rate of lung cancer. The PM size is directly proportional to the health problems in human. The particles with less than 10 mm can cause more severe problems and have more probability of affecting lungs as well as heart. PM can penetrate the lungs, and it can reduce lung functioning.

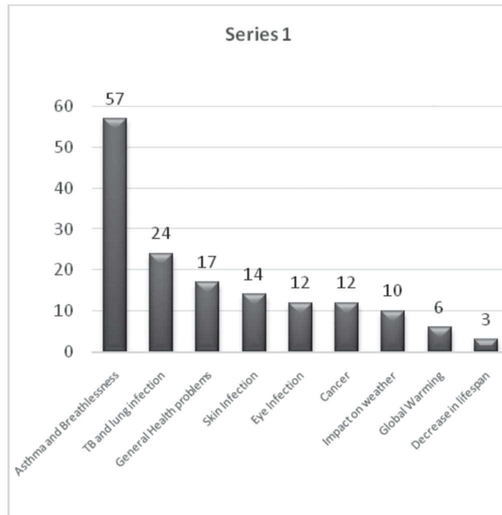

Fig. 4. Disease due to air pollution

PM10 particles are small enough to pass through the throat and nose while breathing and reach the lungs. PM2.5 is smaller than PM10, and it can reach the bloodstream. Children get affected by lung disease easier than adults due to PM in air pollution. Children with lung disease get easily affected by PM and disease gets worse. Mild variation in pollution can be associated with lung functioning. The influence of PM depends on age, gender, medical history. According to WHO ("WHO | Ambient Air Pollution" 2018), 29% lung cancer, 43% COPD, 25% heart disease and 24% of stroke deaths occur due to air pollution.

The PM2.5 health standard is based on the yearly concentration, and it is used for health advisories,

Table 4. Observed Value of PM for all sources

	Crust Material	Sea Salt Spray	Coal Combustion	Road Traffic	Fuel Oil Combustion
$PM_{2.5}$	19.62	10.57	20.12	15.09	15.60
PM_{10}	19.38	10.43	19.88	14.91	15.40

Table 5. Chi-Square Test

	Crust Material	Sea Salt Spray	Coal Combustion	Road Traffic	Fuel Oil Combustion
$PM_{2.5}$	2.23	1.97	1.72	0.24	0.74
PM_{10}	2.26	2.00	1.74	0.24	0.75

and it is shown in Table 6. PM10 is comprised of PM2.5. Short-term exposure worsens the existing diseases, and long-term exposure worsens the disease and reduces the lifetime of human beings. PM10 is less harm when compared with PM2.5. PM10 particles stay for fewer minutes to a couple of hours in the air, whereas PM2.5 stays in the air for days (Liu *et al.*, 2006). During winter, the pollutants are trapped beneath the cloud, and the ratio of pollution in the air is high.

Table 6. $PM_{2.5}$ Health Standard

Range	Standard
0-12.1 µg/m^3	Good
12.1-35.5 µg/m^3	Sensible
35.5-55.5 µg/m^3	Harmful for sensitive groups
55.5-150.5 µg/m^3	harmful
150.5-250.5 µg/m^3	Very harmful
250.5 µg/m^3 and more	Dangerous

Pollution prevention and control

The Air (Prevention and Control of Pollution) Act was introduced in the Parliament of India for controlling air pollution. It was revised in the year 1987("Air (Prevention and Control of Pollution) Act" 2019). India ranks 22 out of 30 moat polluted cities in 2018. Air pollution is one of the reason for early death, around 2 million Indians every year ("Why Is India's Pollution Much Worse than China's? - BBC News" 2019). The National Air Quality Index was introduced by Government of India in collaboration with IIT Kanpur in 2015. In 2019, 'The National Clean Air Programme' was announced with a goal of 20%-30% decrease in particulate matter by 2024.

The Air quality index is used to measure pollutants such as particulate matter, nitrogen dioxide, sulphur dioxide, carbon monoxide, ammonia and lead. The index is based on the colour coded system to mark the health risks. The National Air Quality Index is a measure used to classify the pollution level in the air ("National Air Quality Index" 2019). The National Air Quality Index is shown in Table 7.

The air quality index is used daily for describing air quality. It is used to measure how the quality of air affects human health. The measures are taken by the Environmental protection Agency ("What Is Air Quality Index, AQI Categories, AQI Objectives, AQI News | Business Standard" 2019). When the value of the Air Quality Index is greater, it specifies that the air pollution level is higher, and it leads to health problems. Air quality index is measured using the formula:

$$Air\ Quality\ Index = \frac{Ahigh - Alow}{Bhigh - Blow}(B - Blow) + Alow$$

Here A high indicates the breakpoint corresponds to Bhigh

B indicates the concentration of pollution

Blow indicates concentration breakpoint that is smaller than or equivalent to B indicates concentration breakpoint that is larget than or equivalent to B indicates the breakpoint equivalent to Blow indicates the breakpoint equivalent to Bhigh

The primary air pollutants are shown in Figure 5. In the lower atmosphere of the earth, ozone is created when pollutants discharged by cars, power plants, refineries, chemical plants, and other sources react in the presence of sunlight ("Ozone" 2019). Ozone reaches unhealthy levels during hot sunny days as well as during colder months. Ozone can travel through long distance with the help of wind even to rural areas. Ozone produces serious health problems. Ozone penetrates through the airways and can cause discomfort when breath, reduce lung capacity and generate asthma symptoms. Asthma patients may use an inhaler to relieve from breathing problem.

PM discharged from industries, construction work, diesel and petrol engine emissions are produced by humans. It also comprises of volcanoes, sea spray, pollen and formed in the atmosphere

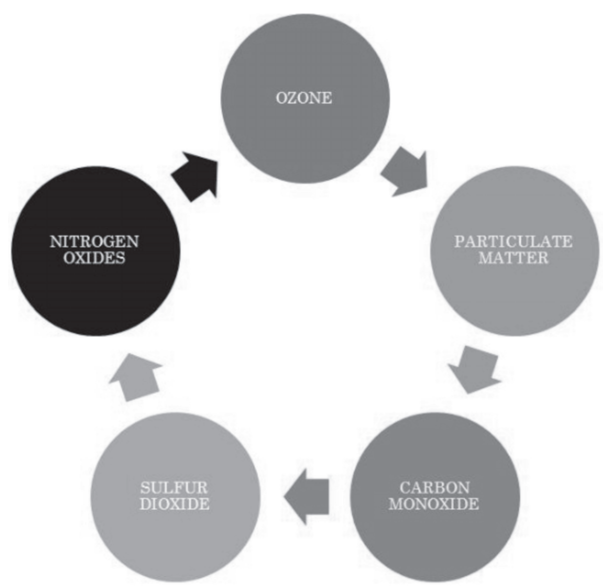

Fig. 5. Air Pollutants

(“Types of Air Pollutants” 2019). PM10 particles can reach airways. PM2.5 reaches the breathing sacs deep, and bloodstream. These particles can carry toxic chemicals which are the reason for cancer. It reacts with people with COPD, asthma, bronchitis and heart conditions.

Nitrogen dioxide is formed by motor vehicles discharge and oxygen combination in the atmosphere. Heaters and gas stoves mainly produce NO2 generated from nitric acid making, welding and using explosives, refining of petrol and metals, commercial manufacturing, and food manufacturing. Disclosure over small timings can exaggerate respiratory diseases, like asthma and even hospital admissions. People with asthma, and kids and the elder people are at high risk for the health effects of NO2 (“Basic Information about NO2 | Nitrogen Dioxide (NO2)” 2019).

Sulphur dioxides are discharged from electric industries by burning fossil fuels,petrol refineries and cement manufacturing. It can move to elongated distances and responsible for the formation of ozone. Sulphur dioxide can aggravate the nose, throat and lungs. It leads to coughing and tightness of the chest and narrowing of the airway, which decreases the flow of air to the lungs. It creates worse conditions like asthma and COPD. People with asthma are susceptible to sulphur dioxide. They may find gasping more difficult when concentrations of sulphur dioxide are high (“Sulfur Dioxide (SO2)” 2019). The AQI breakpoints for various pollutants are shown in Table 8.

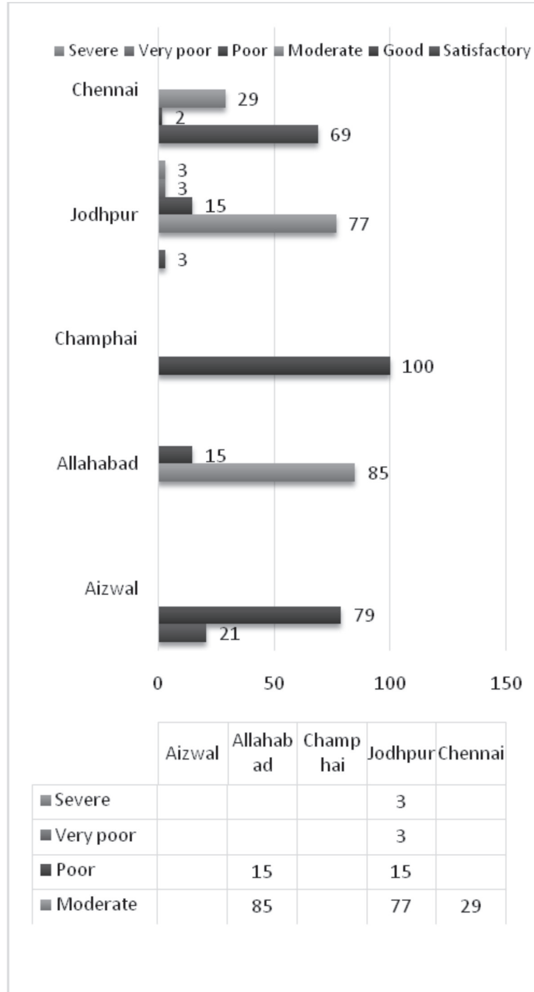

Fig. 6. AQI index of different cities.

Table 7. Air Quality Index

Air Quality Index	Impacts on Health
Good (0 to50)	Less Impact.
Satisfactory (51 to 100)	Minor uneasiness for breathing for easily affecting people.
Midway Polluted (101 to 200)	Breathing uneasiness to people with lung disease.
Poor (201 to 300)	Breathing uneasiness to people on long-lasting disclosure with heart disease.
Very Poor (301 to 400)	Breathing uneasiness to people with lung and heart diseases.
Severe (401 to 500)	Breathing problem can happen even to healthy people.

Table 8. AQI of various pollutants

AQI	PM10	PM2.5	Ozone	SO2	NO2
Good (0 to50)	0-50	0-30	0-50	0-40	0-40
Satisfactory (51 to 100)	51-100	31-60	51-100	41-80	41-80
Moderately Polluted (101 to 200)	101-250	61-90	101-168	81-380	81-180
Poor (201 to 300)	251-350	91-120	169-208	381-800	181-280
Very Poor (301 to 400)	351-430	121-250	209-748	801-1600	281-400
Severe (401 to 500)	430 +	250+	748+	1600+	400+

According to the Central Pollution Control Board, the National Air Quality Index is calculated for 60 cities at 183 locations. In Figure 6, some of the cities air quality index at different locations for July 2019 report is shown.

Decision Tree

Decision Tree is a prognostic approach which distinguishes categories to split the dataset based on specific conditions. It is a supervised learning technique for classification and regression problems. The time complexity is measured by the total number of attributes and records in the given data. The decision tree can produce accurate results (Miloslava, Jirøí, and Pavel 2008). The decision tree algorithm is explained in Figure 7.

The decision tree algorithm is a three-step process. In the first step, data input is to be obtained. In our paper, we obtain the data from the Central Pollution Control Board (“CPCB | Central Pollution Control Board” 2019). The input data are categorized into severe, poor, very poor, moderate, good and satisfactory. The air pollutants used in our paper are NO2, PM10 and PM2.5. The sample air pollutants of the air quality index of July 2019 is shown in Table 9.

The second step is decision making using a decision tree which comprises of root, branches, nodes and leaf. A node with leaving edges is called as an internal node. The remaining nodes are called terminals. Every internal node classifies the occurrence space into more subspaces according to a specific condition of the attribute values.

If there are more than one attributes are selected based on Information gain or Gini index. The information gain is used to calculate approximate data in every attribute. The uncertainty of a random variable is measured by entropy. Information gain computes the predictable decline in entropy due to the categorization of an attribute. The Gini index measures how often an arbitrarily chosen element can be mistakenly recognised. Every leaf is allocated to one class, denoting the suitable final value. Occurences are categorised depending upon the outcome of the test value (Kujaroentavon *et al.,* 2014).

The third step is analysing the data and evaluating the results. For data analysing, data is classified into training data and testing data. Training data

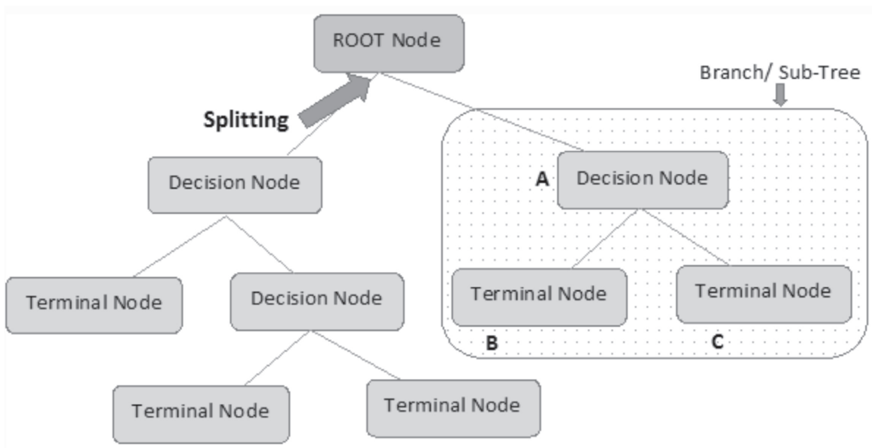

Fig. 7. Decision Tree Algorithm

Table 9. Sample Database for air pollutant

City	Air Quality Index	Status	Parameter
Aizwal	45	Good	PM10
Aizwal	56	Satisfactory	PM10
Allahabad	193	Moderate	PM10
Jodhpur	233	Poor	PM10
Jodhpur	430	Severe	PM10
Kota	31	Good	NO2
Lunglei	6	Good	NO2
Rajahmundri	30	Good	PM2.5
Srikakulam	65	Satisfactory	PM2.5

ratio is 70%, and testing data ratio is 30%. The next step is the attribute selection measure. The dataset is sub-divided into small subsets based on attributes. The next step is evaluation of the model based on performance measures.

The Receiver Operating Curve is graphed using sensitivity on the y-axis and (1-specificity) on x-axis. The ROC curve is used to measure the accuracy of the system, and it depends on the true positive rate and false-positive rate. The ROC curve starts from (0.0) and ends in (1.1). When ROC is found in the diagonal line, there is a 50% chance of decision making correctly. The ROC curve is useful in decision making process (Hajian-Tilaki, 2013). The ROC curve representation is shown in Figure 8.

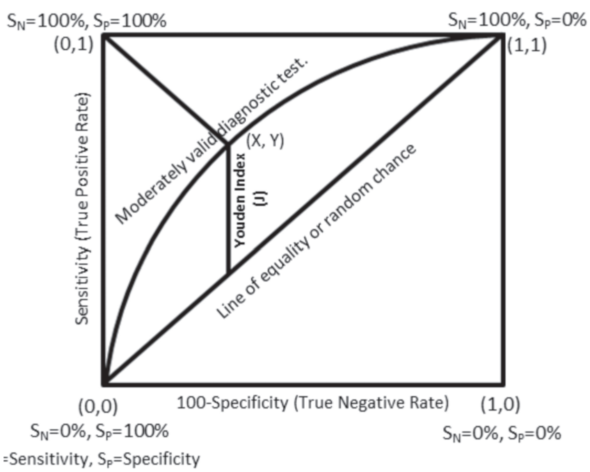

Fig. 8. ROC Curve

ROC curve can be used to select the threshold for a classifier in order to improve true positive rate. The ROC curve is used to measure performance among different classifiers. Decision tree classifier generates a class decision, and it creates a confusion matrix which corresponds to ROC. The predicted probabilities should be sorted in descending order to draw a ROC curve. In the proposed method, we ranked as $PM_{2.5}$>PM_{10}>SO_2>NO_2. Figure 9 shows the ROC curve for the training dataset and testing dataset. The accuracy of the decision tree classifier is 97.2%.

Naive Bayes Classifier

Naive Bayes Classifier based on Bayes theorem, and used to classify an unrealistic assumption. It deals with probabilistic distributions, and it aims to maximise the probability of the target class. The

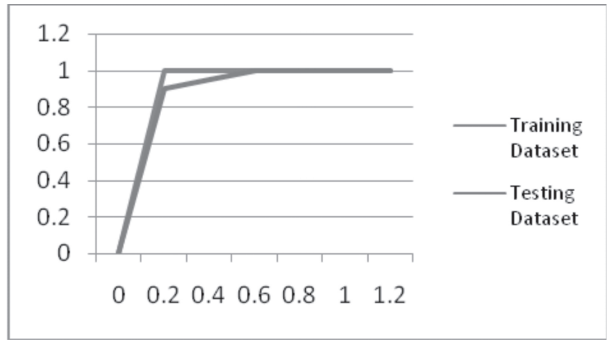

Fig. 9. ROC Curve

Bayesian algorithm is an acyclic graph in which every node represents a random variable, and the arcs represent the relationship between them. Figure 10 represents a Bayesian classification.

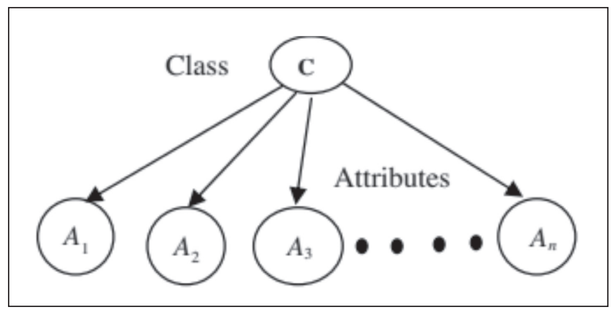

Fig. 10. Bayesian Classification

Let A1, A2, ..., are the attributes in the data set. C is the class attribute with |C| values, c1, c2, ..., c/C. The Bayesian theorem representation is

Where

p(a|b) = chance of occurrence d being in class a.

p(b|a)= chance of creating occurrence d given class a.

p(a)= chance of event of class a.

p(b)= chance of occurrence b occurring.

The Naive Bayes is represented as probabilities. The class probability represents each class in the learning set. The conditional probability denotes class value. It is represented as

P(d|c)= P(d1|c1)*P(d2|c2)*……P(dn|cn)

The classification is a two-step process: a learning phase and the evaluation phase. In the learning phase, the classifier trains model based on a given dataset and in the evaluation phase, it tests the classifier performance. Naive Bayes classifiers have a good accuracy rate on large datasets (Gore and Deshpande, 2017). Figure 11 shows the architecture of Naive Bayes classifier.

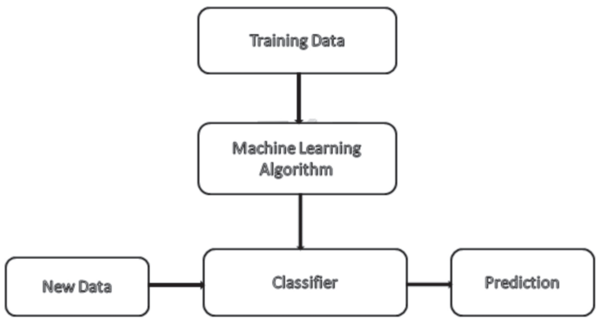

Fig. 11. Naive Bayes Classifier

The Naive Bayes Classifier is a four-step process. The first step is to compute the possibility of the given class labels. The second step is to compute the possibility of every attribute of every class. The third step is to calculate the posterior probability by using Bayes theorem. The last step is to find out the class with a higher probability. The Naive Bayes classifier produces an instance probability. It can be used with a threshold to produce a discrete classifier. The ROC curve for naive bayes classifier is shown in Figure 12. The accuracy of the classifier is 97.9%.

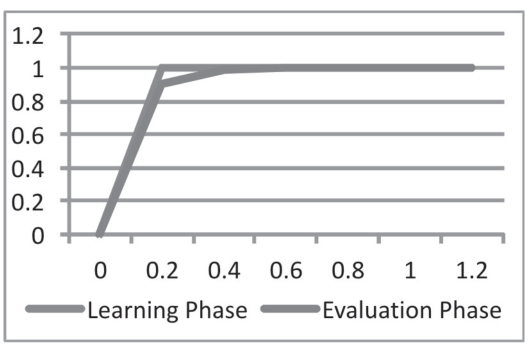

Fig. 12. ROC curve for Naive Bayes Classifier

Conclusion

The National Clean Air Program was launched by India to manage air pollution in 2019. The strategy of the National Clean Air Program is to reduce the air pollutant level by 20% to 30% by 2024. To reduce the air pollutant level, the usage of SO2, NO2 and emission from power stations are to be reduced by using renewable power generation. Vehicle maintenance is to be made mandatory and electric bikes usage is to be encouraged. Burning of crops on open areas is to be banned. To identify the health hazard, we have used decision tree classifiers and naive bayes classifiers. The data are collected from the Central Pollution Control Board which contains air quality index data. The classifiers are trained for very poor, poor, satisfactory, moderate and good. The Naive Bayes Classifier produces good accuracy when compared with decision tree classifier.

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