A case study of air quality data of Ernakulam district

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Abstract. The main objective of an economist is to predict the future of any problem concerning the common man. Considering the human health in India, air pollution becomes a matter of major concern. The present study analyses the air quality data of Ernakulam district in Kerala by assessing various atmospheric pollutants and meteorological factors. The air pollution analysis of southern state, says that Ernakulam district has not been able to sustain the air quality gains of 2020 in the year 2021. As per 2021 air quality categorisation of analysis of days, it is seen that the number of days with worse air quality index has increased two times compared to previous year. The study comes to the conclusion that the meteorological factors have a great impact on the atmospheric pollutants and increasing humidity help to improve pollution. Also, the particulate matters are the major contributer for the increase in air quality index level. The most recent XLSTAT version and python programming were used to infer the results in this study. The researcher contends that, steps are to be taken to reduce the impact of solar radiations which helps in reducing the air quality level.

Keywords : Air Quality Index, Meteorological factors, Air pollution.

1 Introduction

Air pollution in India is a critical environmental issue. India is the fifth most polluted country in the world among 117 countries, territories and regions. As per 2019, out of 30 most polluted cities in the world, 21 were in India. According to a study conducted in 2016, 140 billion Indians breathe air that is 10 times or more over WHO (World Health Organisation) standards. In addition to industrial waste, electricity generation, vehicular emissions, burning biomass, burning crops, etc., there are many other sources of air pollution in various countries and territories. This contributes to premature death of 2 million Indians every year. India is the country among the third largest greenhouse gas producers. Moreover, it is one of the great risk factors which causes disease and in Indian economy, economic cost of air pollution is observed to be exceeding day by day. The analysis of air pollution is one of the crucial tasks and it gains great importance. Because it directly impacts the management of the economic activity in those regions and the health of its inhabitants.

Air quality index (AQI) is usually the standardized formula to indicate how polluted the air currently is. It is a measuring tool of air quality which helps to describe the level of air

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pollution. Also, it is used for simplified public information and data interpretation. Air Quality Index has the scale of about 0-500. Pollution rates are higher when the AQI is high. Air Quality Index can be calculated by taking the maximum value of all the pollutants and naming it as the AQI or bringing up the average of all the pollutant's AQI values. If the Air Quality values ranges from 0-50, it is classified as good, 51-100 as moderate, 101-150 as lightly polluted, 151-200 as not healthy air, 201-300 as most unhealthy or heavily polluted and 301-500 is considered as dangerous. By finding out Air Quality Index, the level of pollution can be determined.

There are various factors contributing to air pollution. $PM_{2.5}$ and PM_{10} are the most common measurements of air quality. Particulate matters or particles are measured in micrograms per cubic meter. Particulate Matter-2.5 ($PM_{2.5}$) consists of fine aerosol particles which is measured 2.5 microns or that are smaller in diameter. This air pollutant is one of six that are routinely measured. It is most harmful to human health as it causes broad range of health effects. $PM_{2.5}$ vary in chemical composition and physical characteristics and is generated from many sources. Sulphates, nitrates, black carbon and ammonium are the common chemical constituents of $PM_{2.5}$. The most common natural sources contributing for $PM_{2.5}$ are dust storms, wildfires, and sandstorms. Particulate Matter-10 (PM_{10}) consists of coarse (bigger) particles of less than 10 microns in diameter. Breathing these particles is harmful to health which causes irritation in eyes, nose and throat. PM_{10} includes dust from roads, farms, construction sites, from industrial sources, pollen and fragments of bacteria, etc.

Nitrogen Oxides (NO_x) is another pollutant which is a mixture of several natural gases Nitric Oxide (NO), Nitrogen Oxide (NO_2), etc. These are a family of highly reactive, poisonous gases and these are formed when fuels are burned at high temperatures. Industrial sources including power plants and boilers also cause emission of these gases. NO_x is a major chemical pollutant which forms atmospheric reactions with the volatile organic components and produces ozone on summer days. It causes damage to the lung tissue, creates breathing and respiratory problems. Safe exposure or permissible level of NO_x is upto 0-80 $\mu g/m^3$ (in 24 hours). Sulphur Dioxide (SO_2) is another pollutant which contains sulphur, such as coal and oil and it is mainly produced from fossil fuel combustion. These can cause many respiratory problems such as asthma, bronchitis, wheezing and also coughing which leads to cardiovascular disease. By burning coal, releases SO_2 into the environment which is a threat to human health and plant life. Permissible level concentrations of SO_2 in atmosphere are 20 $\mu g/m^3$ on 24-hour average. Other pollutants like Ammonia (NH_3), Carbon monoxide (CO), Ozone (O_3) also contribute to air pollution. Ammonia (NH_3) leads to increase in acid depositions and excess level of nutrients in soil, river, etc., have harmful effects on aquatic ecosystems and cause damage to forests, other vegetations. In the presence of sunlight and stagnant air, nitrogen oxides react with volatile organic compounds to produce Ozone (O_3), a secondary polluant. Carbon monoxide (CO) if inhaled, causes reduce in the amount of oxygen which should be transported in the blood stream to heart and brain. Breathing CO can even cause death.

Many chemical reactions take place in the atmosphere and results in the emission of various pollutant gases. The meterological factors such as wind speed and direction, humidity, temperature, rainfall and solar radiations help in understanding these chemical reactions that occur in the atmosphere. When the air is cool, the pollutants cannot spread out quickly and thus it builds up and increases the concentration. But when strong or erratic winds blow, the pollutants distribute very fastly and results in low pollutant concentration. Measuring temperature helps in forecasting activities. In the atmosphere, chemical reactions that form photochemical smog from other pollutants are influenced by temperature and sunlight (solar radiation). Water vapour is another important factor that take part in many photochemical and thermal reactions in the atmosphere. The water molecules attach to SO_2 and forms acid rain which causes damage to plant and animal health. When the temperature and rainfall are higher, humidity will also be higher. Rainwater dissolve many gaseous particles such as SO_2 and it also becomes a reason for formation of acid rain.

In Kerala, Ernakulam districts stands in moderate rating in the real-time cleanest city ranking of air quality as per 2021. On this context, statistics plays an important role in analysing each and every economic problem. This emission of gases in atmosphere and the factors that are responsible for their formation can be reduced by proper analysis of them. Government can take better decisions if good suggestions are made. In this paper, the collected data contains 7 atmospheric pollutants $PM_{2.5}$, PM_{10}, NO_x and SO_2 and their Air Quality Index (AQI) value. It also includes the meterological factors like rainfall, temperature, humidity, solar radiation and wind speed. The study primarily aims to analyse the major factors responsible for pollution.

2 Statement of the problem

Air Quality Index (AQI) is a measure that determines quality of the air. It aims to inform people about the air they are breathing as well as which groups of people might be affected. An individual can also take measures to prevent exposure to air pollution. Air Quality Index concentrates on the health effects caused by breathing polluted air within a few hours or days. In this situation, this paper aims to conduct a study by analysing the air quality data of Ernakulam district in Kerala. The main objective of this study is to find out the relationship among pollutants and meteorological factors. For this study, the air quality data of Ernakulam district in Kerala, for the year 2021 are used. The dataset contains daily data from 01/01/2021 to 31/12/2021 with atmospheric pollutant rates of $PM_{2.5}$, PM_{10}, NO_x, SO_2, CO, O_3, NH_3 and overall AQI value. The data also includes meteorological factors like humidity, temperature, rainfall, wind speed and solar radiation. The data is collected from Kerala State Pollution Control Board, Pattom, Trivandrum.

3 Objectives of the study

- Analysing the air quality data and finding out the major factors responsible for pollution.
- Finding out the relationship between the atmospheric pollutants and the meteorological variables.

4 Hypothesis

1. Atmospheric pollutants are not strongly related to each other.
2. There is a significant relationship between the atmospheric pollutants and the meteorological variables.

5 Statistical Analysis

For the study of air quality index, the collected data contains the details of 365 days in the year 2021, but as a sample, only data for one day is displayed here.

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Table 1. Sample of Data collected for study for 1 day.

Attributes	Description	Value
PM_{10}	Inhalable particulate matter concentration (µg/m³)	62
$PM_{2.5}$	Fine particulate matter concentration (µg/m³)	62
SO_2	SO_2 concentration (µg/m³)	5.82
NOx	NO_x concentration (ppb)	29.72
NH_3	NH_3 concentration (µg/m³)	4.26
CO	CO concentration (mg/m³)	1.06
O_3	O_3 concentration (µg/m³)	2
WS	Wind speed (m/s)	0.8
WD	Wind direction (degree)	17
SOL_RAD	Solar Radiation (watt/m2)	139
TEMP	Temperature (℃)	26.7
RH	Relative humidity (percent)	67
RF	Rainfall (mm)	0
AQI	Air quality index value(1day)	106.67
AQI level	Air quality index level	Lightly polluted

The graph shown below in Fig. 1 is a multiple bar graph representing the month wise pollution rate of each atmospheric pollutant taken under study. Compared to other pollutants, it can be seen that $PM_{2.5}$ has a higher pollution rate ranging from 0 to 193. PM_{10} is the second contributor to pollution showing a high range of rating between 0 and 135.6. SO_2 has shown a high rating of 170.95 in the month of March but on other days it ranges between 0 to 44 which is comparatively smaller. NOx ranges between 0 and 97 which is not exceeded above 100. From the graph it is clear that CO is a least contributor for pollution. O3 ranges between 0 to 50. It is visible that NH_3 also has a least rating of pollution.

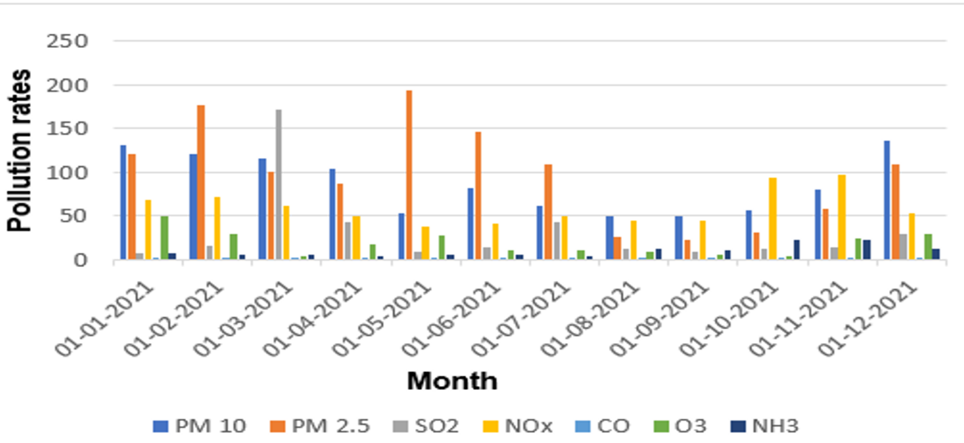

Fig. 1. Graph of atmospheric pollution rates in 2021.

Table 2. Descriptive Statistics.

	N	Minimum	Maximum	Mean	Std Deviation	Variance	Skewness	Kurtosis
PM 10	365	6	135.63	51.54	26.89	723.29	0.90	0.14
PM 2.5	365	7	193	39.46	28.18	793.91	1.50	3.49
SO2	365	0.02	170.97	8.46	12.27	150.65	8.12	94.84
NOx	365	11.41	96.9	40.25	13.71	187.86	1.41	2.33
CO	365	0.19	1.88	0.91	0.20	0.04	-0.42	2.82
O3	365	0	49	6.31	7.19	51.66	2.06	5.11
NH3	365	0.03	22.46	6.51	4.61	21.23	1.28	1.01
AQI	365	27.5	356.15	88.62	54.18	2935.05	2.07	4.95
WS	365	0.3	1.35	0.65	0.15	0.02	1.36	3.73
WD	365	1	57	27.55	14.29	204.17	0.24	-1.39
TEMP	365	22.5	29.9	26.97	1.30	1.70	-0.43	0.25
RH	365	52	93	75.96	7.56	57.13	-0.29	-0.14
RF	365	0	363.6	6.82	30.12	906.95	8.35	80.23
SOL_RAD	365	0	276	176.23	54.82	3005.64	-0.15	-0.49

The above table shows the relationship among the atmospheric pollutants and overall air quality index rate. The correlation coefficients among the seven pollutants PM_{10}, $PM_{2.5}$, SO_2, NO_x, CO, O_3, NH_3 and AQI were calculated.

Table 3. Correlation analysis.

	PM_{10}	$PM_{2.5}$	SO_2	NO_x	CO	O_3	NH_3	AQI
PM_{10}	1	0.62	0.13	0.10	0.42	0.34	-0.20	0.53
$PM_{2.5}$	0.62	1	0.16	-0.10	0.40	0.33	-0.40	0.90
SO_2	0.13	0.16	1	-0.10	0.29	0.05	0.03	0.20
NO_x	0.10	-0.10	-0.10	1	0.003	-0.05	0.70	0.12
CO	0.42	0.40	0.30	0.003	1	0.13	-0.10	0.40
O_3	0.34	0.33	0.05	-0.05	0.13	1	-0.20	0.31
NH_3	-0.20	-0.40	0.03	0.70	-0.10	-0.20	1	-0.16
AQI	0.53	0.90	0.20	0.12	0.40	0.31	-0.16	1

From the data analysis in Table 3, it can be obtained that Nitrogen oxides in the air pollution index and the other three pollutants except the inhalable Particulate matter, Ammonia and Carbon monoxide all show coefficients of negative correlation. There is no linear relationship between Carbon monoxide and Nitrogen oxides as the coefficient value tends to zero. The Pearson correlation coefficients of inhalable Particulate matter shows a very low positive correlation with 0.1 value which is negligible. It is also obtained from the table that Ammonia in the Air pollution index and the other four pollutants except the Sulphur dioxide and Nitrogen oxide all show negative correlation coefficients. The correlation coefficient with Sulphur dioxide is 0.03 which is negligible. But Nitrogen oxides and Ammonia show a high positive correlation with coefficient 0.7. Depending on the amount of Nitrogen deposits in the soil, Ammonia increases along with Nitrogen which can directly damage vegetation or it can cause changes to species composition. Also, microbes in the soil produce Nitrogen oxides and release into the atmosphere. Also, reduction of Nitrogen oxides in the atmosphere results in formation of Ammonia. Therefore, they have a positive correlation with each other.

Between the two groups of pollutants, fine Particulate matter ($PM_{2.5}$) and inhalable Particulate matter (PM_{10}) has the largest value of the correlation coefficient, and it reached 0.62. The pollution concentrations of fine particles and Carbon monoxide, Ozone, all show almost significant correlations, with Pearson correlation coefficients as 0.42 and 0.34 respectively. Sulphur dioxide and Nitrogen oxides are not significant with coefficients 0.13 and 0.10 respectively. Based on our practical observation, we know that incomplete combustion of fossil fuels results in emission of Carbon monoxide and these are often accompanied with other gaseous pollutants emission and emission of Particulate matter to a small extent. Ozone is also formed from the chemical reactions between certain pollutants which are emitted from vehicles and during the combustion of fossil fuels. These also result in emission of Particulate matter along with them up to a small extent. Therefore, we see that they have a slightly positive correlation among each other and between fine Particulate matter and inhalable Particulate matter.

Now, considering the Air quality index rate, the fine Particulate matter shows a coefficient of 0.9 which is a very high positive correlation. Ammonia shows negative correlation. Nitrogen oxides and Sulphur dioxide shows a very low positive correlation with coefficient 0.12 and 0.20 respectively. Ozone and Carbon monoxide are low positive correlated with coefficients 0.31 and 0.40 respectively. Inhalable Particulate matter shows significantly positive correlated with 0.53 value of coefficient. The inference is that fine Particulate matter has a major role in increasing the Air quality index level. Inhalable Particulate matter also contributes to a significant level in increasing AQI level. Sulphur dioxide, Carbon monoxide and Ozone are less contributors to Air quality index level but have more impact than Ammonia and Nitrogen oxide. From these findings, we can conclude that the atmospheric pollutants are not strongly related to each other and accept the null hypothesis.

The below table shows Pearson correlation coefficients in the statistical analysis for finding relationship among the seven atmospheric pollutants and the meteorological factors of air pollution. From Table 4, we can get that there are varying values of correlation between the meteorological factors (Wind speed, Temperature, Relative humidity, Rainfall and Solar radiation) affecting air pollution and the seven atmospheric pollutants. We can see that the relative humidity has a very small effect on the atmospheric pollutants, as all the five pollutants except Nitrogen oxide and Ammonia are negatively correlated. Nitrogen oxides is of negligible correlation with coefficient 0.10. This concludes that increase in relative humidity can improve the pollution rate.

We can see that the temperature have significant effect on the seven pollutants, and it has a slight linear relationship between the inhalable Particulate matter and Carbon monoxide in the atmosphere and the temperature. Fine Particulate matter and Ozone have negligible correlation coefficients of 0.15 and 0.08 respectively. Sulphur dioxide, Nitrogen oxides and Ammonia are negatively correlated. We know from practical experience that solubility of Ammonia decreases as temperature increases. This concludes that increase in temperature results in decrease of these atmospheric pollutants.

Table 4. Correlation analysis between pollutants and meteorological variables.

	PM_{10}	$PM_{2.5}$	SO_2	NO_x	CO	O_3	NH_3
WS	-0.01	0.003	0.09	-0.19	0.03	-0.03	-0.24
TEMP	0.34	0.15	-0.01	-0.17	0.30	0.08	-0.20
RH	-0.70	-0.45	-0.20	0.10	-0.45	-0.38	0.30
RAIN FALL	-0.09	-0.07	0.01	0.22	-0.07	0.01	0.27
SOL_RAD	0.24	0.25	0.26	-0.17	0.32	0.26	-0.23

Wind speed can be seen as having a negligible correlation coefficient with fine Particulate matter, Sulphur dioxide and Carbon monoxide and is slightly negatively correlated with other four pollutants. Wind speed is to be taken into consideration when storm or cyclone related disasters happen. Here, it can be avoided since the wind blow is normal throughout the year. Rainfall has very slight negative correlation with inhalable Particulate matter, fine Particulate matter and Carbon monoxide. It has negligible correlation with sulphur dioxide and Ozone in the atmosphere. Nitrogen oxides and Ammonia have low positive correlation with rainfall. Rainfall was higher in the winter season. Heavy rainfall can increase Nitrogen leaching and denitrification, also it leads in explosive release of Ammonia from soil. Therefore, these pollutants are positively correlated with rainfall.

Solar radiations or sunlight has low positive correlations with all five pollutants except Nitrogen oxide and Ammonia which is negatively correlated. These produce results opposite to rainfall as we can observe. The heat increases emissions of pollutants like Particulate matters, Sulphur dioxide, Carbon monoxide and Ozone which results in increase in pollution rate. These findings infer that there is a significant relationship between the atmospheric pollutants and meteorological factors and thus we can accept our null hypothesis.

6 Conclusion

Through the analysis of the daily data of the year 2021, the Pearson correlation coefficient were calculated among the 7 atmospheric pollutants ($PM_{2.5}$, PM_{10}, SO_2, NO_x, O_3, CO and NH_3) and the air quality index value. Also, the correlation between the seven pollutants and meteorological factors (TEMP, RH, WS, RAIN FALL and SOL_RAD) were statistically analysed. The experimental results prove that the atmospheric pollutants are not strongly related to each other. And the meteorological factors have a great impact on the atmospheric pollutants. The study provided a new knowledge in the sector of Air quality analysis. The overall Air quality index level is moderate as per 2021. The major factor responsible for increase in pollution rate was the Particulate matters. Considering the meteorological factors, Solar radiations contribute to increase in the overall pollution rate and increase in humidity causes decrease in pollution rate.

References

1. Chen. Chao, Byung. Won. Min., Correlation Analysis of Atmospheric Pollutants and Meteorological Factors based on Environmental Big Data, International Journal of Contents Vol.**18**, Issue No. 01, 3 (2022).
2. Yu. Hui. D, Ruo. Rong. L., Correlation analysis of AQI characteristics and meteorological conditions in heating season, International Conference on Energy Equipment Science and Engineering, Vol. **4** (2019).
3. Aarthi, P. Gayathri, N. R. Gomathi, S. Kalaiselvi, Dr. V. Gomathi, Air Quality Prediction through Regression Model, International Journal of Scientific & Technology Research Vol No. **9**, Issue No. 03, 3 (2020).
4. Era. Upadhyay, Mugdha. Nayak, Jhumoor. Biswas, Air Quality Status of Lucknow City - A Case Study, International Journal of Engineering Research and Technology, Volume **5**, Issue 12, (2016).
5. C. Fahe, Review and Prospect of my country's Air Pollution Control Process, Environment and Sustainable Development, Vol. **45**, Issue No. 3, (2020).
6. Sharma. D, Mauzerall. D., Analysis of Air Pollution Data in India between 2015 and 2019, Aerosol Air Quality Research. Journal, Volume **22,** Issue 2, February (2022).
7. Sathidevi. C, The Reasons for Dropouts of Adult Learners in Adult Education Centers in Kerala - A Case Study, International Journal of Advanced Research in Science and Engineering, Vol. No.**07**, Issue No. 03, March (2018) UGC Approved Journal.

8. Akhil. M. Nair., Sidharth. S. Prasad., Sreelatha. K. S., Case Study – How to Bridge the gap between present Education System and employability in Kerala State, International conference on Physics and Photonics Processes in Nano Sciences, IOP Publishing, Journal of Physics: Conference Series Vol.**1362**, (2019).
9. Vishnu. Manoj, Sarika. S. G, Raji. P. and Lincy. Thomson., An analysis of dropout students in education System of Kerala, International conference on Physics and Photonics Processes in Nano Sciences, IOP Publishing, Journal of Physics: Conference Series vol.**1362**, (2019).
10. Nayana. Madhu, Ponnu. Soman, Sathidevi. C., Covid Pandemic-Parents Concern on Higher Education: International Journal of Mechanical Engineering, Vol. **7** No. 1 January, (2022).
11. Malavika. V. R. and Lasitha. A., The Impact of Examination malpractices among Higher secondary students in Kerala - A case study, International Journal of Mechanical Engineering, Vol. **7** No. 1 January, (2022).
12. Ponnu. Soman, Nayana. Madhu, Sathidevi. C., Impact of Covid-19 Pandemic on Education in Schools of Kerala State, International Journal of Mechanical Engineering, Vol. **7** No. 1 January, (2022).