Interplay of Climate Change and Air Pollution – An Analysis of Air Quality in Puducherry Union Territory

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सत्यमेव जयते
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Hope, the report will be useful to all concerned.

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1. Introduction

U.T of Puducherry consist of the four former colonies of French India namely Puducherry, Karaikal, Yanam and Mahe. Puducherry and Karaikal regions are located in south-eastern Coromandel Coast of India, surrounded by Tamil Nadu state. Yanam surrounded by Andhra Pradesh state is located farther north along the eastern coast in the delta region of the River Godavari and Mahe is located on the western Malabar Coast, surrounded by Kerala state. The U.T's capital is the city of Puducherry, north of Cuddalore. The Union Territory of Puducherry comprises an area of 492 Sq.Kms. It is currently stands as the 29th most populous and the third most densely populated state/UT in India.

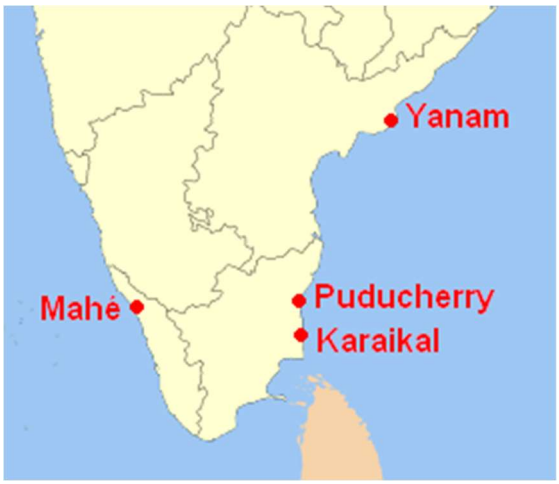

Figure1: Map showing four regions of U.T of Puducherry

2. Air Pollution

The atmosphere is a layer of gases surrounding the earth, which mainly composes nitrogen and oxygen (99% by volume) and other gases including water vapor contribute to about 1%. Rapid urbanization and industrialization have imposed additional elements/compounds to the clean air causing an increase in pollution. In order to prevent, control and abate air pollution, the Air (Prevention and Control of Pollution) Act was passed in 1981. According to Section 2(b) of Air (Prevention and Control of Pollution) Act, 1981 'air pollution' has been defined as 'the presence in the atmosphere of any air pollutant.' As per Section 2(a) of Air (Prevention and Control of Pollution) Act, 1981 'air pollutant' has been defined as 'any solid, liquid or gaseous substance (including noise) present in the atmosphere in such concentration as may be or tend to be injurious to human beings or other living creatures or plants or property or environment'. Therefore, ambient air quality standard is developed as a policy guideline that regulates the effect of human activity upon the environment so that pollutant discharge into the air can be regulated.

3. Interplay of Climate Change and Air Quality

Air pollution and climate change are closely interrelated. The main sources of CO_2 emissions such as the extraction and burning of fossil fuels not only act as major climate change enforcers but also as key sources of air pollutants. Furthermore, several air pollutants that are considered to be destructive to human health and ecosystems also add to climate change by altering the proportion of incoming sunlight that is reflected or absorbed by the atmosphere. Some of these pollutants cause a warming effect while the other pollutants cause a cooling the Earth thereby inducing the climate change. Such air pollutants are collectively called as short-lived climate-forcing pollutants (SLCPs) consisting of black carbon, methane, ground-level ozone, and sulfate aerosols. Together these air pollutants impose a considerable impact on the climate; especially black carbon and methane are considered to be the major contributors to global warming after CO_2.

3.1. Impact of air quality on climate change

Nitrogen oxides, sulphur dioxide, ammonia, and volatile organic compounds are all precursors of secondary aerosols. These aerosols are reflective in nature thereby scattering the solar radiation back into space and have a negative (cooling) radiative forcing of climate. They also influence the radiative properties of clouds. Thus, reductions in the precursors of secondary aerosols are likely to lead to increases in temperatures and there is evidence that the cooling effects of sulphate aerosol may have partially masked the warming effects of greenhouse gases.
Black carbon is a product of incomplete combustion. In the context of air quality, it is measured as black smoke. Black carbon absorbs solar radiation and black carbon aerosols, or mixtures of aerosols containing a relatively large fraction of black carbon, exert a positive (warming) radiative forcing of climate. This effect is especially noticeable when the black carbon aerosol is situated above reflective surfaces like clouds or snow and ice.

The climate impact of methane, carbon monoxide, hydrogen and some volatile organic compound species via ozone production is reinforced by their impact on the lifetime of methane. However, for nitrogen oxides emissions effects of methane lifetime on climate and the time-integrated ozone production are approximately equal in magnitude but opposite in sign, with a high degree of uncertainty in both. For ground-based sources, the net climate effect of nitrogen oxides emissions on methane and ozone may be negative to some extent and for aviation, it could be slightly positive. In general, combustion sources with a typical ratio of nitrogen oxides to carbon dioxide emissions have a net radiative forcing due to nitrogen oxides which are a hundred times smaller than that because of the co-emitted carbon dioxide.

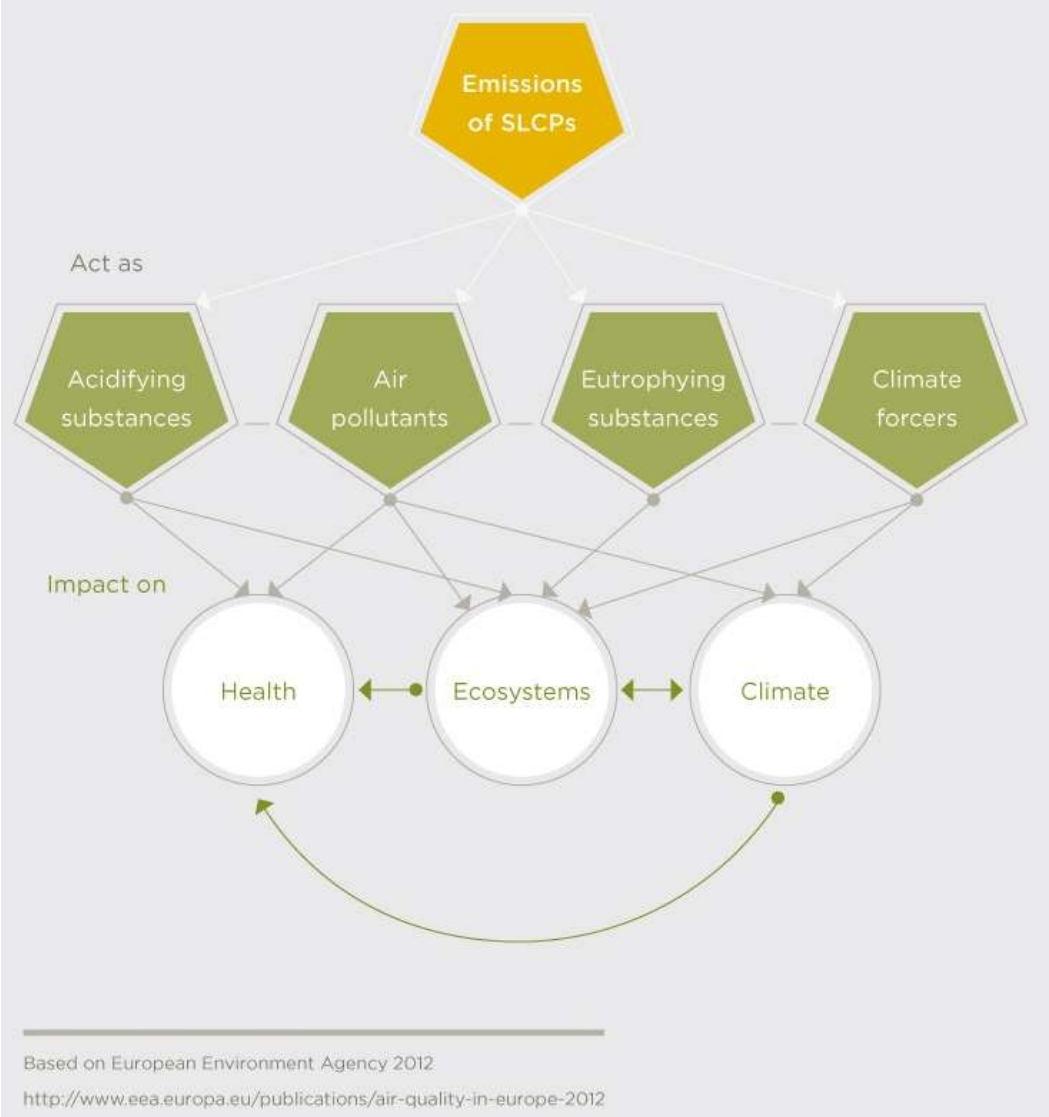

Figure 2: Air pollution and climate change

Air pollutants can also have important effects on concentrations of carbon dioxide and methane through their impacts on ecosystem sources and sinks. These include effects of sulphate deposition in reducing methane emissions from major natural sources, effects of nitrogen deposition in increasing plant growth and thus carbon uptake, and effects of ozone in reducing plant growth and carbon uptake. Greenhouse gases are the most effective higher troposphere, where greater radiative impact is felt also accompanied by lower temperatures. The effect of aerosols is also notably controlled by its altitude. The concentration of pollutants at the surface is the most significant issue in air quality.

3.2. Impact of climate change on air quality

Increase in temperature as the climate changes will lead to changes in the chemistry associated with ozone formation. The greatest effect will be observed on the change in concentration of water vapour, which will lead to ozone shrink in the background troposphere and increases polluted regions where there are higher nitrogen oxides concentrations. There could also be an increase in the flux of ozone from the stratosphere to the troposphere.

4. Need for Air Quality Monitoring from Climate Change Perspective

The key findings from this Air Quality Monitoring report will provide a handful of information that can be incorporated into climate adaptation planning. This presents a window of opportunity that could be useful for designing and demonstrating a pathway forward to support adaptation into the future. We note that the Government of Puducherry has a progressive greenhouse mitigation program, and has a relatively advanced policy in climate adaptation. Together, this likely shapes and explains the receptivity and advancement of adaptation among four regions of the U.T.

5. National Ambient Air Quality Standards (NAAQS)

The objectives of air quality standards are:

- To show the levels of air quality necessary with an adequate margin of safety to protect the public health, vegetation and property.
- To assist in establishing priorities for abatement and control of pollutant level.
- To provide uniform yardstick for assessing air quality at national level.
- To indicate the need and extent of monitoring programme.
- The MoEF & CC has notified the revised National Ambient Air Quality Standards notified on November 2009. The same can be viewed at http://cpcb.nic.in/National_Ambient_Air_Quality_Standards.php

5.1. Protocol of measurement and Interpretation

The Annual Arithmetic mean of minimum 104 measurements in a year at a particular site taken twice in a week 24 hourly at a uniform interval. 24 hourly 08 hourly or 01 hourly monitored values, as applicable shall be complied with 98% of the time in a year. They may exceed the limits 2% of the time, but not on two consecutive days of monitoring.

Note: Whenever and wherever monitoring results on two consecutive days of monitoring exceeds the limit specified for the respective category, it shall be considered adequate reason to introduce continuous monitoring and further investigation.

5.2. National Ambient Air Quality Monitoring Programme

The ambient air quality is monitored at 593 locations in 249 cities, towns and industrial areas across 28 States and 5 Union Territories by Central Pollution Control Board (CPCB) in association with the concerned State Pollution Control Boards and Pollution Control committees for UTs under National Air Monitoring Programme (NAMP). SO_2, NO_2, and PM_{10} are the key parameters monitored under the NAMP.

Puducherry Pollution Control Committee is carrying out manual ambient air quality monitoring at six locations in the U.T. of Puducherry under the NAMP of CPCB. In Puducherry this programme is supported by Puducherry Climate Change Cell by funding the purchase of eight respiratory dust samplers and two $PM_{2.5}$ samplers apart from providing technical assistance.

5.3 Locations of air quality monitoring

The monitoring of pollutants is carried out for 24 hours (4-hourly sampling for gaseous pollutants and 8-hourly sampling for particulate matter) with a frequency of twice a week.

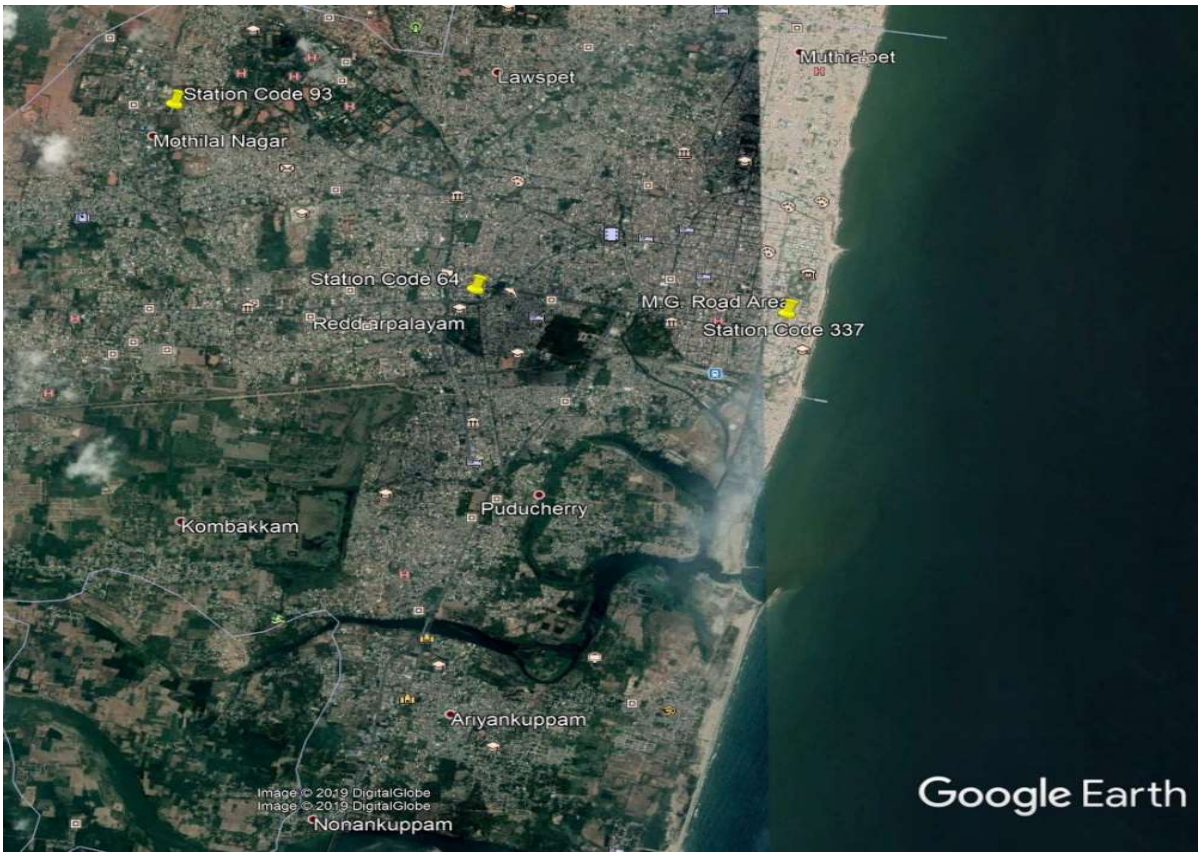

Figure 3: Map showing the sample stations along with station code located in Puducherry region

Table 1: Locations of air quality monitoring

Sl. No.	Location Name	Location Type	Source of pollution	Station Code	Co-ordinates
1	Local Administrative Department Building (LAD), Suffren Street, Puducherry.	Residential area	Vehicle emission and natural dust from road	337	11° 55' 46.55" N 79° 49' 58.32" E
2	Dept of Science Technology and Environment Building (DSTE), Anna Nagar, Puducherry.	Residential cum Commercial area	Vehicle emission and natural dust from road	64	11° 55' 54.55" N 79° 48' 33.86" E
3	Electricity Department, Mettupalayam Industrial Estate (PIPDIC), Puducherry.	Industrial area	Industrial Pollution and vehicular pollution.	93	11° 56' 56.50" N 79° 47' 11.84" E
4	B.Ed. College, Nehru Nagar, Karaikal	Residential area	Vehicle emission and natural dust from road	784	10º 56' 24.8" N 079º 50' 02.2" E
5	Govt. Guest House, Kovilpathu, Karaikal	Residential cum Commercial area	Vehicle emission and natural dust from road	785	10º 55' 49.4" N 079º 49' 52.6" E
6	PPCL, Polagam, T.R. Pattinam, Karaikal	Industrial area	Industrial Pollution and vehicular pollution.	786	10º 51' 08.0" N 079º 49' 51.8" E

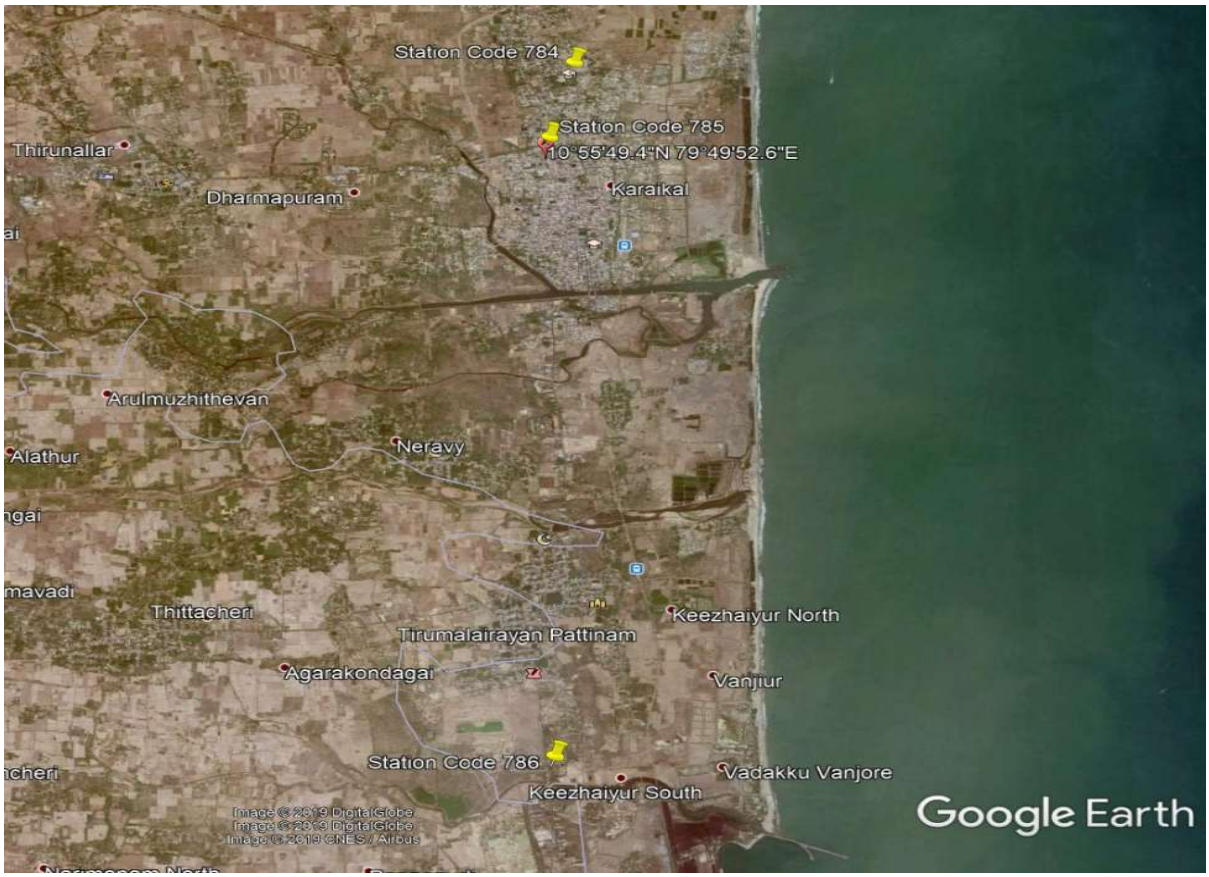

Figure 4: Map showing the sample stations along with station code located in Karaikal region

5.4 Objectives of Air Quality Monitoring

- To determine status and trends of ambient air quality;
- To ascertain whether the prescribed ambient air quality standards are violated;
- To Identify Non-attainment Cities;
- To obtain the knowledge and understanding necessary for developing preventive and corrective measures

5.5 Parameters monitored under Air Quality Monitoring:

Three criteria pollutants viz. PM_{10} (Particulate Matter having an aerodynamic diameter less than 10 or equal to 10 μm), sulphur dioxide (SO_2) and nitrogen dioxide (NO_2) were identified for regular monitoring at all locations.

5.6 Methods of Measurement:

Table 2: Air pollutant and methods of measurement

S.No	Air Pollutant	Method of measurement
1	Particulate Matter – PM_{10} (size less than 10 microns)	Gravimetric
2	Nitrogen dioxide	Improved West and Gaeke method
3	Sulphur dioxide	Modified Jacob and Hochheiser

6 Source and Effects

6.1 Particulate Matter (PM_{10})

Particulate matter is considered to be the primary pollutant, if its chemical form remains the same, even after emitted into the atmosphere. The primary particulate matter consists of windblown dust like road dust, fly ash, soot etc. Particulate matter is called secondary pollutant when it is formed by chemical reactions in the atmosphere. Secondary pollutant particulate matter include sulphates, nitrates etc. Particulate pollution generally causes health-related problems like increased respiratory symptoms, such as irritation of the airways, coughing, or difficulty breathing, decreased lung function; aggravated asthma; development of chronic bronchitis; irregular heartbeat; nonfatal heart attacks; and premature death in people with heart or lung disease. Environmental effects of particulate matter includes visibility reduction, aesthetic damage etc.

6.2 Sulphur dioxide (SO_2)

Sulphur is mainly present in raw materials such as coal, crude oil, and ore. Sulphur dioxide is formed when coal, crude oil are burnt. The diesel driven vehicles are the specific source of sulfur dioxide generated during the combustion process. Effects of SO_2 include respiratory illness, visibility impairment, acid rain and aesthetic damage.

6.3 Nitrogen Oxide (NO_2):

Nitrogen oxides are formed when fuel is burned at high temperature. Sources of nitrogen oxides include vehicles, industrial processes that burn fuel. Oxides of nitrogen along with VOCs results in the formation of ground-level ozone, which can trigger serious respiratory problems, crop damage.

7. Status of Air Quality

Annual Average concentration of pollutant for the years 2016, 2017 & 2018 in six locations in the U.T of Puducherry is tabulated in table 3.

Table 3: Status of Air Quality

S. No	Location	Pollutant in µg/m^3								
		PM_{10}			SO_2			NO_2		
		2016	2017	2018	2016	2017	2018	2016	2017	2018
1	LAD	34	34	38	5.6	4.2	3.5	13	11.5	10.4
2	DSTE	43	48	46	6.1	5	4.1	14.5	13.7	12.9
3	PIPDIC	43	42	45	6.3	5	4.1	14.9	13.1	12.1
4	B.Ed college	30	45	35	8.7	5.8	3.1	7.4	8.1	6.1
5	Govt Tourist Home	42	46	43	13.8	9	4.5	10.5	11	8.1
6	PPCL	42	49	40	13.2	10.1	3.9	10.6	11.8	7.3
STANDARD		60			50			40		

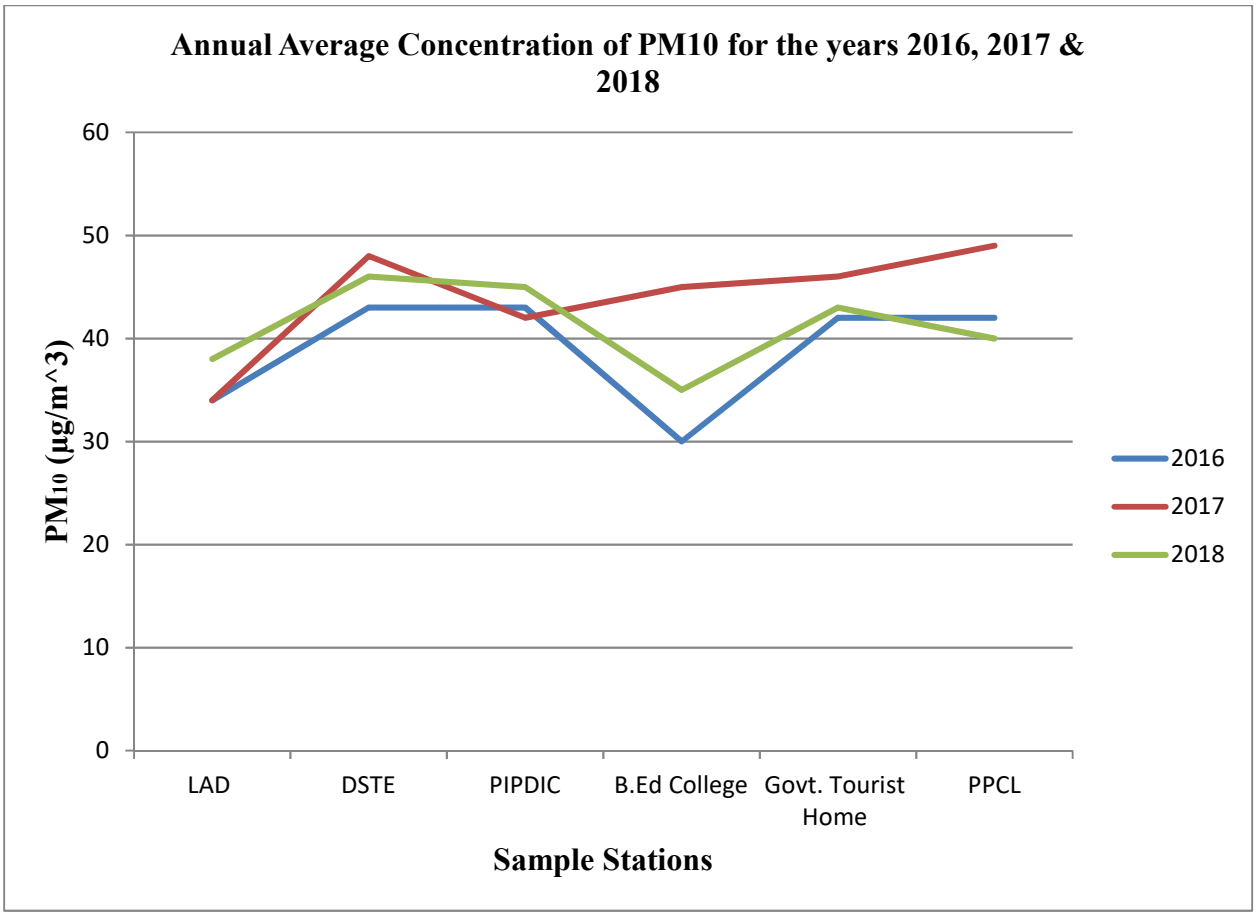

Figure 5: Annual Average Concentration of PM_{10} for the year 2016

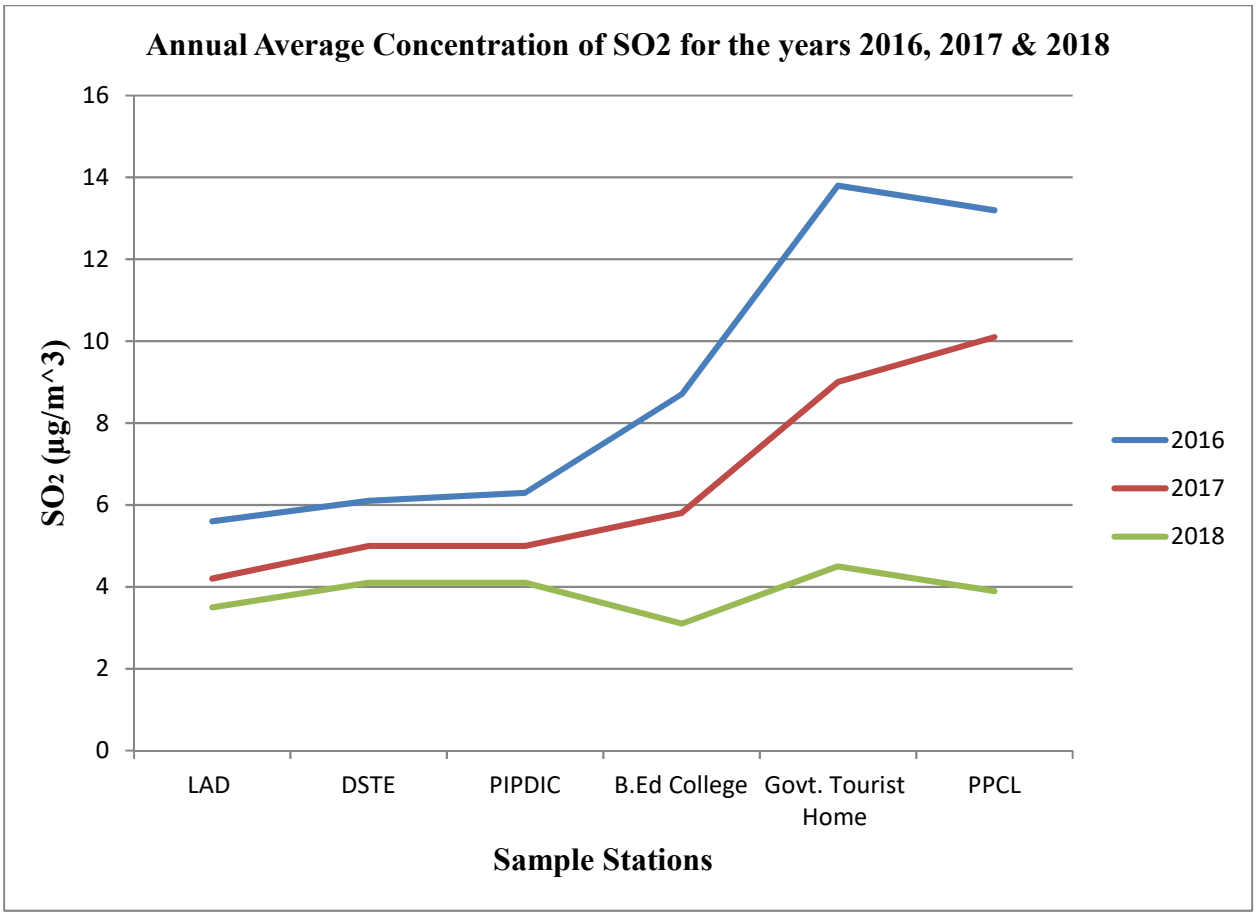

Figure 6: Annual Average Concentration of SO_2 for the year 2016

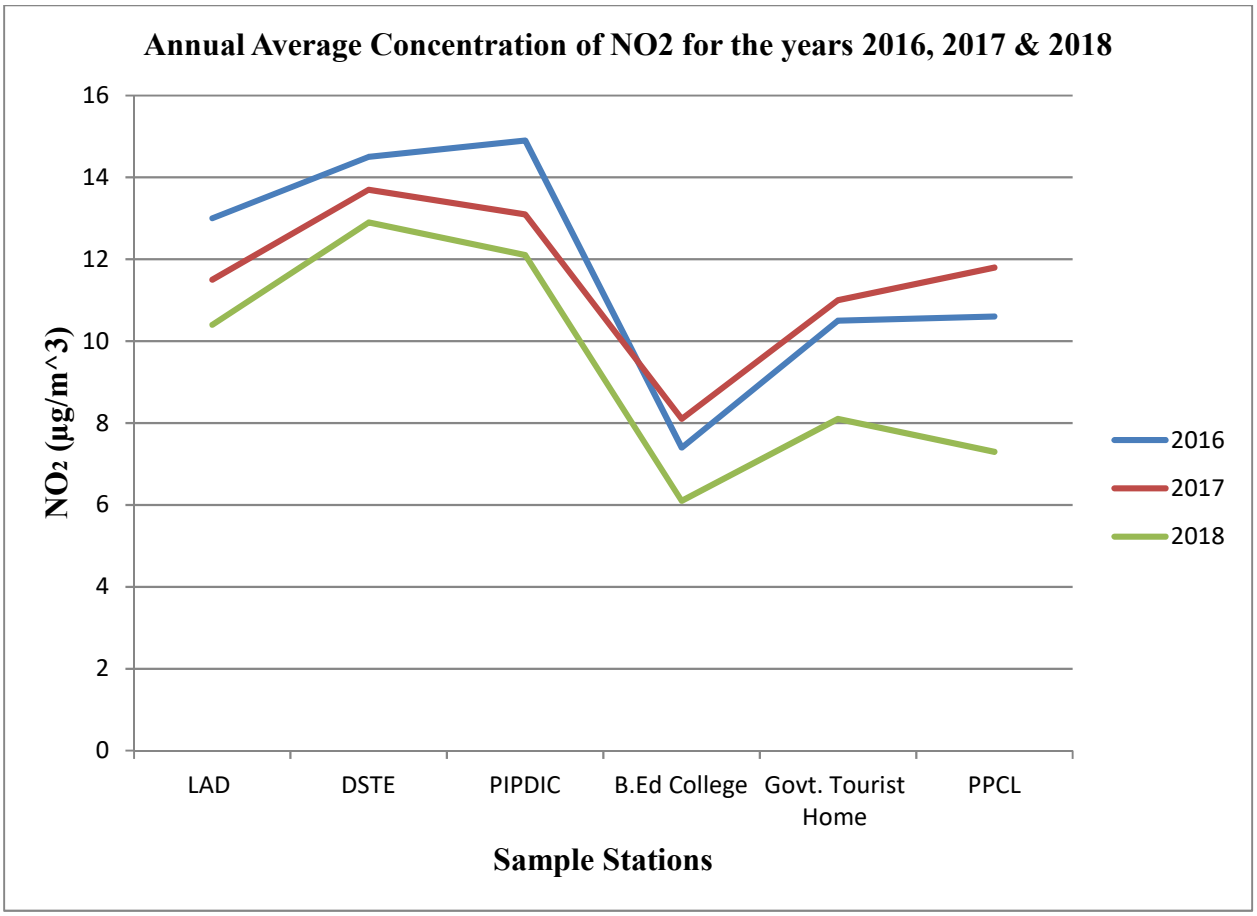

Figure 7: Annual Average Concentration of NO_2 for the year 2016

8. Results and Observations:

Annual average concentrations of Respirable Suspended Particulate Matter in the ambient air monitored in all the six locations are found to be in the range from 30-49 ($\mu g/m^3$) which is well within the prescribed standard limit of 60 $\mu g/m^3$.

Similarly, Annual average concentrations of SO_2 and NO_2 in the ambient air monitored in all the six National Air Quality Monitoring locations are within the standard limit of 50 $\mu g/m^3$ and 40 $\mu g/m^3$ respectively. The Major reason for such low levels of pollution in Puducherry is that it has excellent ventilation effects due to sea and land breezes like any other coastal city, which considerably decreases the levels of pollution

It is also observed from the figures 5, 6 & 7 that the annual average concentrations of the pollutants viz., SO_2 & NO_2, especially in Puducherry region, was found to be declining trend since 2016.

Changes in the emissions of air quality pollutants such as sulphur dioxide, nitrogen oxides, particulate matter, and ammonia have significant implications for global warming. At the same time as these pollutants are not themselves important as greenhouse gases, they influence the formation of pollutants such as ozone which acts as a greenhouse gas. They are also associated with the formation of airborne particles whose effect is generally (although not exclusively) to reduce surface air temperatures thus lessening the effects of global warming.

Broadly speaking, reductions in the emissions of gases such as sulphur dioxide, nitrogen oxides, and ammonia which lead to the formation of airborne particles will result in increased global warming. From the figures 6 & 7 it is observed that the annual average concentrations of the pollutants viz., SO_2 & NO_2 decreases gradually which is in correlation with the increasing trend of global warming.

This decrease in the annual average concentrations of SO_2 & NO_2 further adds to global warming by increasing the average surface temperature which kept increasing during the past three years. This is not to say that these pollutants should not be reduced, as they have significant local and regional impacts, but there may need to be a balancing of priorities.

Overall, the monitoring result reveals that the annual average concentrations of the pollutants in all the six National Air Quality Monitoring locations are within the prescribed standard limits.

9. Air Quality Index:

Air Quality Index may be a tool for effective communication of air quality condition to public in a simple and understand method that is easy to grasp. It transforms complicated air quality information of several pollutants into a single number (index value), nomenclature and colour.

There are six AQI classes, specifically named as Good, Satisfactory, Moderately polluted, Poor, Very Poor, and Severe. Each one of these classes or categories is determined based on the ambient concentration values of air pollutants and their possible health impacts (known as health breakpoints). AQ sub-index and health breakpoints are developed for eight pollutants (PM_{10}, $PM_{2.5}$, SO_2, NO_2, O_3, CO, NH_3, and Pb) for which short-term (up to 24-hours) National Ambient Air Quality Standards are prescribed.

During the past three years (2016, 17 &18) 80 to 85 % of AQI values fall under the AQI category “Good”, whereas 17 to 25 % of AQI values fall under the AQI category “Satisfactory”.

Table 4: Health Impacts

AQI	Possible Health impacts
Good (0-50)	Minimal Impact
Satisfactory (51 - 100)	Minor Breathing discomfort to sensitive people
Moderate (101 - 200)	Breathing discomfort to the people with lung, heart disease, children and older adults
Poor (201 -300)	Breathing discomfort to people on prolonged exposure
Very Poor (301-400)	Respiratory illness to the people on prolonged exposure
Severe (>400)	Respiratory effects even on healthy people

On the whole AQI gives clear view about ambient air and the report reveals that PM_{10} is predominantly responsible to determine the air quality which can be easier for a common man to understand. The PM_{10} concentration in the Puducherry and Karaikal region is sourced predominantly from the anthropogenic activity, which may be due to the increase in vehicle movement, road dust etc.

Detailed consideration should be given to developing better means of expressing the influence of air quality pollutants on climate, and for inter-comparing the benefits of abatement strategies in respect of air quality and of climate change. The number of sampling stations can also be enriched in future for improved data acquisition. Sampling should also be done at Mahe and Yanam region to cover the all four regions of U.T of Puducherry.

10. Broad guidelines for Public/Citizens:

AQI is associate degree initiative meant to boost public awareness and involvement in efforts to improve air quality. People can contribute by maintaining vehicles properly (e.g. get PUC checks, replace car air filter, maintain right tyre pressure), following lane discipline & speed limits, avoiding prolong idling and turning off engines at red traffic signals. Additionally, during severe or very poor AQI, people should reduce travel; keep away from using private vehicles and as an alternative use public transport, bikes or walk, and carpool.

Over the past few decades attention has been centered mainly on the mitigation of air quality (AQ) impacts through legislation and technology up gradation. In mitigating these impacts, little or no consideration has been given to the impacts (beneficial or detrimental) on climate. These two policy areas have for the most part developed separately from each other. Measures to limit

Climate Change are aimed at the long-term while mitigation policies for Air quality have relatively shorter time ranging from 10 to 15 years. The significance of the connection between these two policy areas was increasingly recognized. Several different types of mitigation measure can be broadly identified and categorized. These include:

- Conservation: reducing the use of resources through energy conservation.
- Efficiency: carrying out the same activity, but doing so more efficiently, thus reducing resource use and emissions of AQ and climate-active pollutants.
- Abatement: the application of a technological approach to reducing emissions. Fuel switching: substituting a lower emission fuel for a higher emission fuel.
- Solid waste management: dump yards are major source for the methane emission therefore solid waste in U.T of Puducherry should be managed properly; options like waste to energy plant must be considered for treating the solid waste.
- Behavioral change: changing the habits of individuals or organizations in such a way as to reduce emissions e.g. traveling by train instead of by air.

Though these measures can be brought through legislation, fiscal instruments, voluntary agreements, and technology up gradation the public participation is very important for successful implementation of these measures.

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