CUMULATIVE PARTICULATE MATTER ASSESSMENT OF KERALA GIDC USING AERMOD

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Abstract: Air pollution is the major concerned pollution amongst all the types of pollutions like water pollution, land pollution, noise pollution, ground water contamination etc. Air pollution may be the result of natural sources or natural occurrences or human activities. Rapid increase and revolution in industrialization and increase in population are major reasons considered for increased air pollution in current era. Diminution of air pollution is the most important because it affects biotic as well as abiotic components present on the planet Earth. To diminish the air pollution, the first step shall be monitoring of air quality. Assessment of air pollutants emitted from industrial activities is necessary. The present study is focused on assessment of cumulative Air Pollution in terms of Particulate Matter of Kerala GIDC assuming all industries as multiple point sources using AERMOD software.

***Index Terms* – AERMOD, Dispersion Model, Ground Level Concentration.**

I. INTRODUCTION

Air pollution is the presence of any foreign substances in the ambient atmosphere, mostly due to any human activity, in sufficient concentration, for sufficient time, and with the circumstances of interfering significantly with the comfort, health or welfare or with the full use or enjoyment of the properties for each and every living being, including humans Air pollution may be the result of emerging industrialization and automobiles. Air pollution may be due to natural occurrences or human activities.

As we know, Pollution is the biggest concern of any country, especially developing countries, like ours, amongst all types of pollutions, Air Pollution is said to be a 'Silent Killer'. Thousands of people are trying to be survived from the adverse health effects due to air pollution, which have become a major and global issue now-a-days and people are continuously finding ways for escaping from the jaw of this Silent Killer.

In June, 1972, the United Nations Conference on Human Environment was held at Stockholm, Sweden and was attended by then Prime Minister Hon'ble Indira Gandhi and she stated that "Poverty is the biggest polluter."

In India, current air quality is at alarming level, all parameters i.e. SO_X, NO_X, PM_{10}, $PM_{2.5}$ etc. are going beyond the limits prescribed by the Ministry of Environment, Forests & Climate Change vide its Notification No. G.S.R. 826(E), dated 16th November, 2009 regarding National Ambient Air Quality Standards (NAAQS), and hence focus on the quality of ambient air shall be the top most priority of the country like ours.

II. LITERATURE REVIEW

Many research papers related to the studies carried out worldwide by using AERMOD dispersion model for various purposes is studied. The studied papers contain study of various parameters and its impact on health as well as environment by using AERMOD. AERMOD uses a Gaussian and a bi-Gaussian approach in its dispersion models. It generates hourly, daily, monthly as well as annual concentrations of pollutants in ambient air [13]. AERMOD dispersion model is now-a-days widely used in carrying out the study of Environmental Impact Assessment. In the country like India, submission of Environmental Impact Assessment (EIA) Report is mandatory as per EIA Notification, 2006 and amendments thereafter. The US Environmental Protection Agency's short term atmospheric dispersion model (AERMOD) is a good candidate for radiological dose calculations to the general public and Environment [1]. AERMOD gives effective results in the measurement of odor dispersion. To assess the perception of odours using dispersion models such as AERMOD and CALPUFF, a simple averaging time scaling factor can be used to estimate short-term peak concentrations [2]. Surface roughness has the greatest impact on prediction other than albedo and surface roughness [3]. Actual land use parameters shall be measured and its impact on ground level concentration can be evaluated. AERMOD gives effective measurement of PM_{10}. Long term as well as short term impacts can be identified by using AERMOD. A limitation of AERMOD may be the scarcity of air sampling data to compare to exposure estimates [8]. AERMOD can be run successfully for all types of pollutants sources, i.e. point, area and volume sources. Globally, albedo and Bowen ratio have less effects on concentration patterns than the roughness length, this is to be expected since albedo and Bowen ratio only affect the retention of incoming solar radiation, and therefore have no effect at night or just during convective conditions [9]. Concentration contours shows that maximum ground level concentrations may follow or may not follow the predominant wind direction [13].

III. AERMOD

AERMOD is one of the popular Gaussian type air dispersion model which is based on Planetary Boundary Layer (PBL) and Similarity relationship theory. AERMOD is regulatory model in USA, since 2005 and recently Australia has also recommended AERMOD as regulatory model for air quality modeling purpose. It is an updated version of the Industrial Source Complex (ISCST3) model being proposed by the USEPA for assessing air quality management purpose. In this study, emission data of flue gas stack of industries located within Kerala GIDC for parameters like exit stack gas velocity, stack gas temperature, stack height, stack inside diameter etc are required to be fed as input to AERMOD. Meteorological data required as input are wind speed, wind direction, dry bulb temperature, solar radiation, % relative humidity, hourly precipitation, cloud cover etc.

About approximately 30 years ago, the establishment of National Ambient Air Quality Standards (NAAQS) was occurred. The impact of any future source or activity on air quality can be easily identified using dispersion modeling. The need to assess and compare the air quality with NAAQS due to existing and future activities was felt by U. S. Environmental Protection Agency (USEPA). In 1991, the formal collaboration between the American Meteorological Society (AMS) and the U.S. Environmental Protection Agency (EPA) was initiated with the designed goal of introducing current planetary boundary layer (PBL) concepts into regulatory dispersion models.

A working group (AMS/EPA Regulatory Model Improvement Committee, AERMIC) comprised of AMS and EPA scientists were formed for this collaborative effort. In most air quality applications one is concerned with dispersion in the PBL, the turbulent air layer next to the earth's surface that is controlled by the surface heating and friction and the overlying stratification. The PBL typically ranges from a few hundred meters in depth at night to 1 - 2 km during the day time.

Now-a-days, there are many active Air Pollution Dispersion Models being used widely, like CALPUFF, ISCST 3, SCREEN, AERMOD, Gausian Plume Dispersion Model etc. However, AERMOD is most widely used Air Pollution Dispersion Model, which can be run with the use of Meteorological parameters as well as Emission data.

AERMOD is one of the most popular air dispersion model, which works on the concept of steady-state Gaussian Plume type model. In the country like USA, AERMOD has been a regulatory model since 2005, and then after many other countries like Australia, India etc. have now recommended AERMOD for monitoring air quality. Result or performance of AERMOD depends mainly on parameters like surface roughness, Bowen ratio and albedo.

In AERMOD, mainly three components are used:
1. AERMET – estimate boundary layer for dispersion
2. AERMAP - used to compute height of receptors & source
3. AERMOD - steady-state Gaussian Plume model

Major inputs required for the assessment of cumulative air pollution of Kerala GIDC are of two types, which are mentioned as under:

Emission Data
- stack gas emission rate (g/s),
- exit stack gas velocity,
- stack inside diameter,
- stack height,
- stack gas temperature

Meteorological Data
- wind speed
- wind direction
- dry bulb temperature
- solar radiation,
- % relative humidity
- hourly precipitation
- cloud cover etc.

Input to AERMOD is fed through excel sheets in prescribed formats. AERMOD may generate daily, monthly as well as annual concentrations of pollutants in the ambient air. AERMOD model has following mentioned three components:

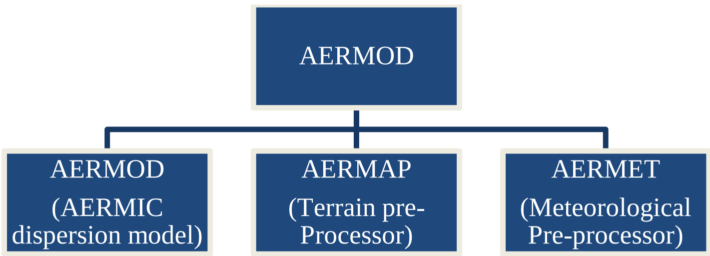


Figure 1: Components of AERMOD

AERMAP (Terrain Pre-processor):

AERMAP is a terrain pre-processor designed to simplify and standardize the input of terrain data for the AERMOD. AERMAP has high flexibility in the specification of receptor locations. The receptors are specified in the AERMAP terrain pre-processor in a manner identical to the AERMOD dispersion model. Discrete receptors as well as Cartesian and polar grid networks are well specified by AERMAP. The user can specify the receptor coordinates in either universal transverse Mercator (UTM) coordinate system or any other user coordinate system. Output data includes location and height scale for each receptor.

AERMET (Meteorological Pre – processor):

Boundary layer parameters used by AERMOD is calculated mainly by the use of AERMET. AERMET input interims of hourly wind speed, wind direction, dry bulb temperature along with surface characteristics in the form of Albedo , Surface Roughness and Bowen ration which are associated with land use land cover (LULC). Then AERMET calculates other parameters like Friction velocity, Monin Obukhov length, convective velocity scale, surface heat flux which determines the stability of the PBL. The AERMET module is a three stage processing routine. In first stage, extraction of the data from the two sets of data presented and subjecting it to quality assurance checks in the form of acceptable data ranges occurs. In second stage, all data available are merged in to a single data file. The third stage establishes the boundary layer parameters from the merged data and generates the two meteorological files which are read by the AERMOD module.

1. Surface data file
2. Profile data file

Calculations of the boundary layer parameters are dependent on the surface conditions in the vicinity of the facility being modeled. Obstacles to wind flow, surface moisture and reflectivity all affect the calculation and are quantified by the assignment of three variables: surface roughness length, surface albedo, and Bowen ratio. Data flow of AERMOD is as follows:

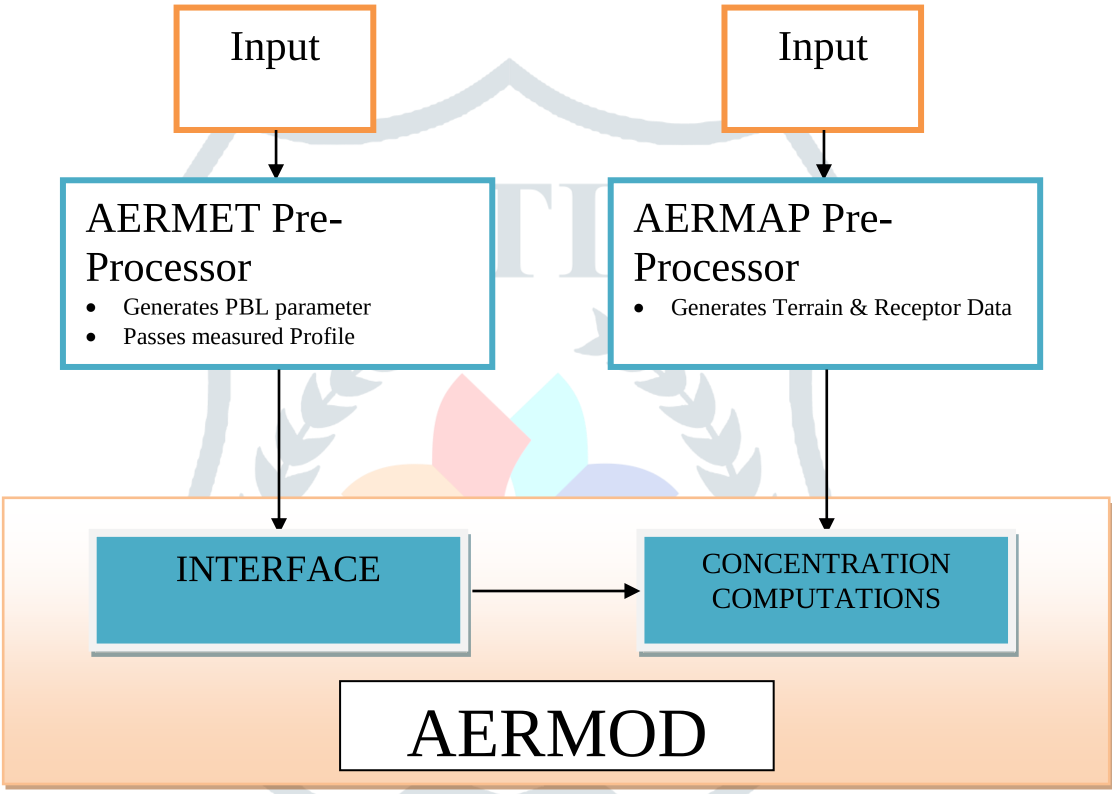


Figure 2: Data flow of AERMOD

IV. HIGH VOLUME AIR SAMPLER

High Volume Air Sampler (HVAS) is the Air Monitoring Instrument, which is basically used to collect the air particles.

- **MECHANISM OF HIGH VOLUME AIR SAMPLER:**

As shown in figures, the air particles get passed through the filter and leave the sampler through Exhaust, while the contaminants get trapped on the filter.

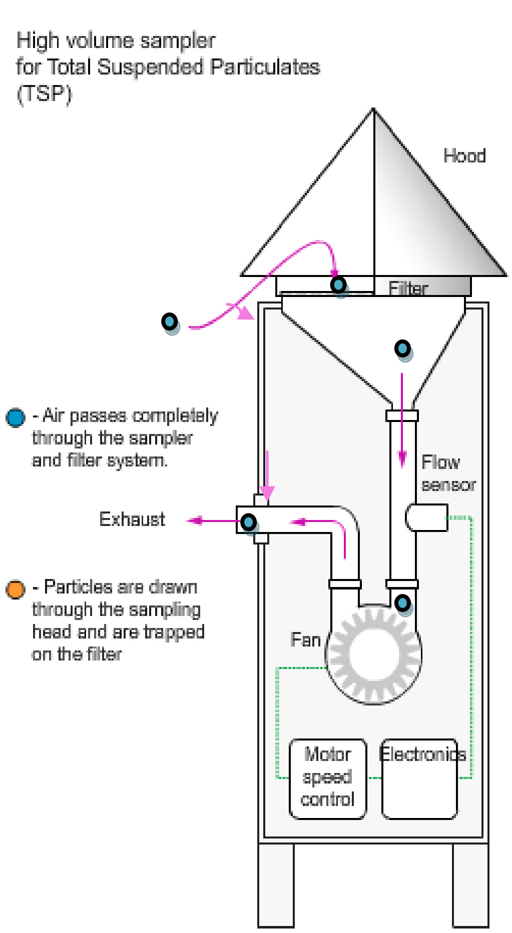


Figure 3: Air Particle gets passed through HVAS

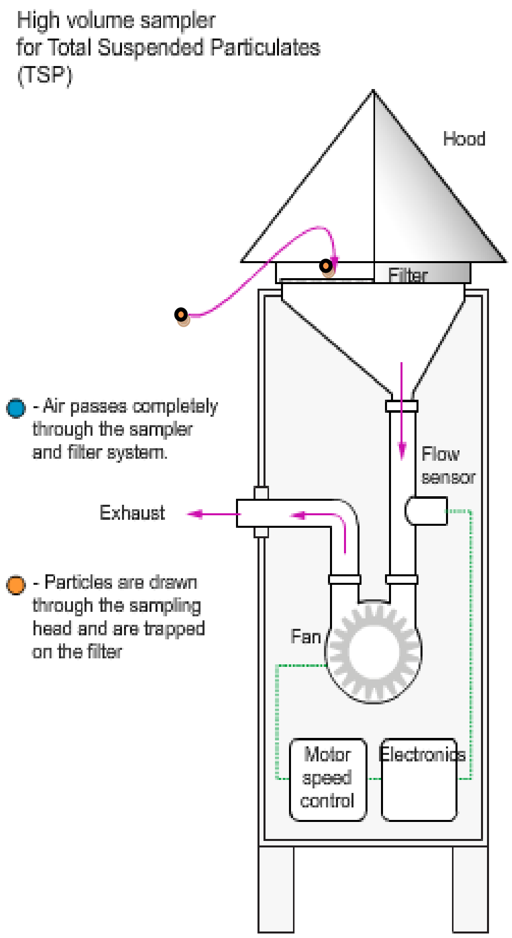


Figure 4: Contaminant gets trapped in the filter of HVAS

PRINCIPLE:

- It collects suspended particulates on filter paper
- Standard filter rate: 20 to 60 standard cubic feet per minute (SCFM)
- Large amount of particles from 0.1 to 1 gram are collected over 24 hour of time

PROCEDURE OF SAMPLING:

- Note down the initial weight of filter paper as (W1)
- Place the filter paper in HVAS
- Set the time as per the monitoring plan
- Note down the initial reading of time (T1)
- Start the monitoring
- Measure the flow rate of air passing through filter with the help of manometer
- Note down the final reading of time (T2)
- The difference gives sampling time. (T2-T1)
- Take out the filter paper from Repairable Dust sampler assembly
- Note down the weight of filter paper as (W2)
- The difference in weight (W2-W1) gives Repairable suspended particulate Matter

CALCULATION:

Calculation of Volume of air Sampled:

$$V = Qt$$

Where,
V = volume of air sampled m^3
Q = average flow rate, in m^3/min
T = total sampling time, in min

Calculation of RSPM in ambient air

$$\text{RSPM (as } \mu g/m^3) = [(W1 - W2) \times 10^6] / V$$

Where,

W1= initial of filter, in g
W2 = final weight of filter, in g
V = Volume of air sampled in m^3
10^6 = Conversion of g to μg

V. DESCRIPTION OF THE STUDY AREA

Kerala GIDC is located at 22.7779° N, 72.3251° E, approximately 40 km away from Ahmedabad and 30 km away from Nalsarovar Bird Sanctuary. Kerala GIDC is situated 9 km away from Bavla Taluka of Ahmedabad District. The population of Bavla municipality is 42,458 & that of Kerala village is 1,560 (As per Census 2011), air pollution of GIDC may affects adversely on the residents of village, especially on infants and senior citizens. Kerala GIDC is situated approximately 35 km away from Nalsarovar Bird Sanctuary, which is a habitat for so many foreign birds in winter season. There are many types of industries, some of the major industrial sectors located within GIDC are pharmaceutical industries, food & beverages industries, ceramic industries, pesticide industries, electric vehicle manufacturer, pigment manufacturers, iron & steel, engineering units, waste handling units etc.

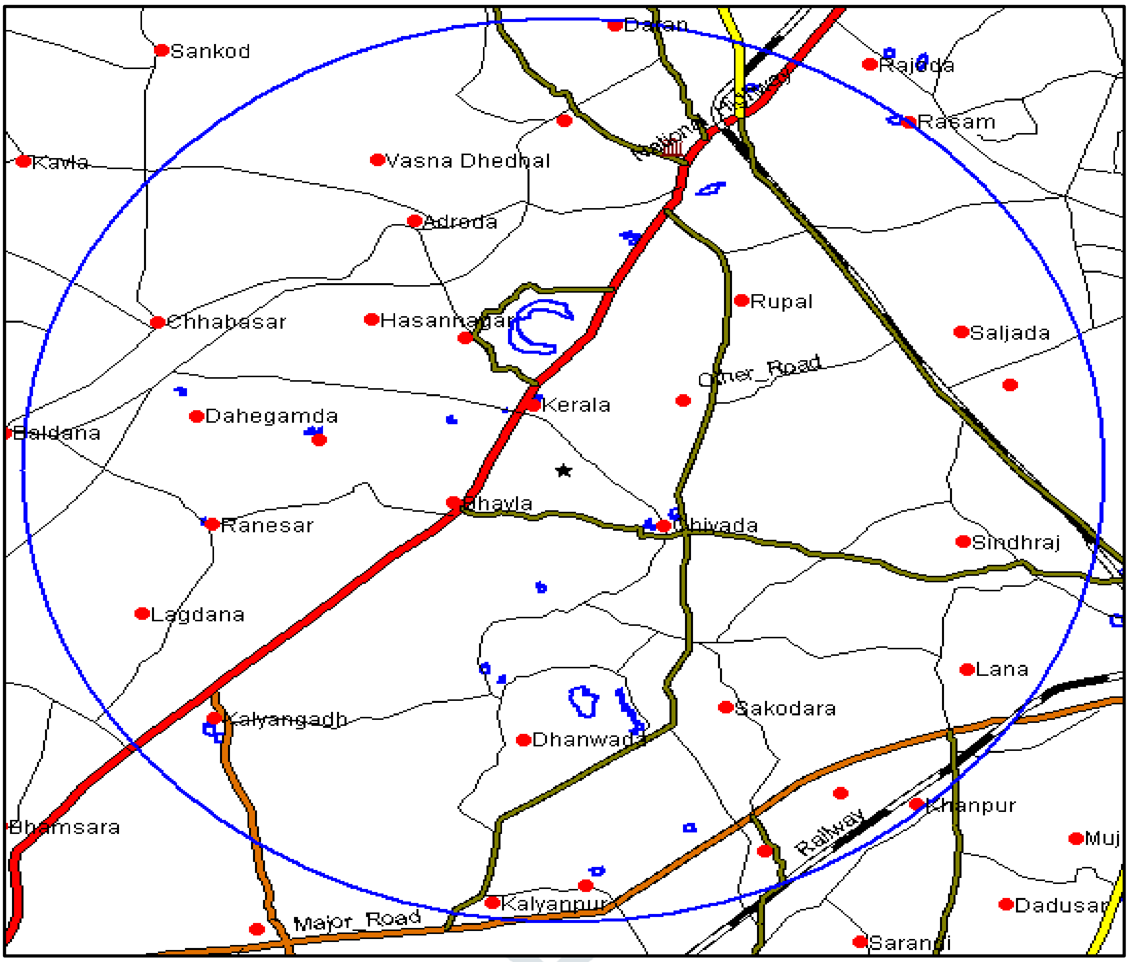


Figure 5: 10 km Radius Map of Kerala

- **WINDROSE DIAGRAM OF THE AREA**

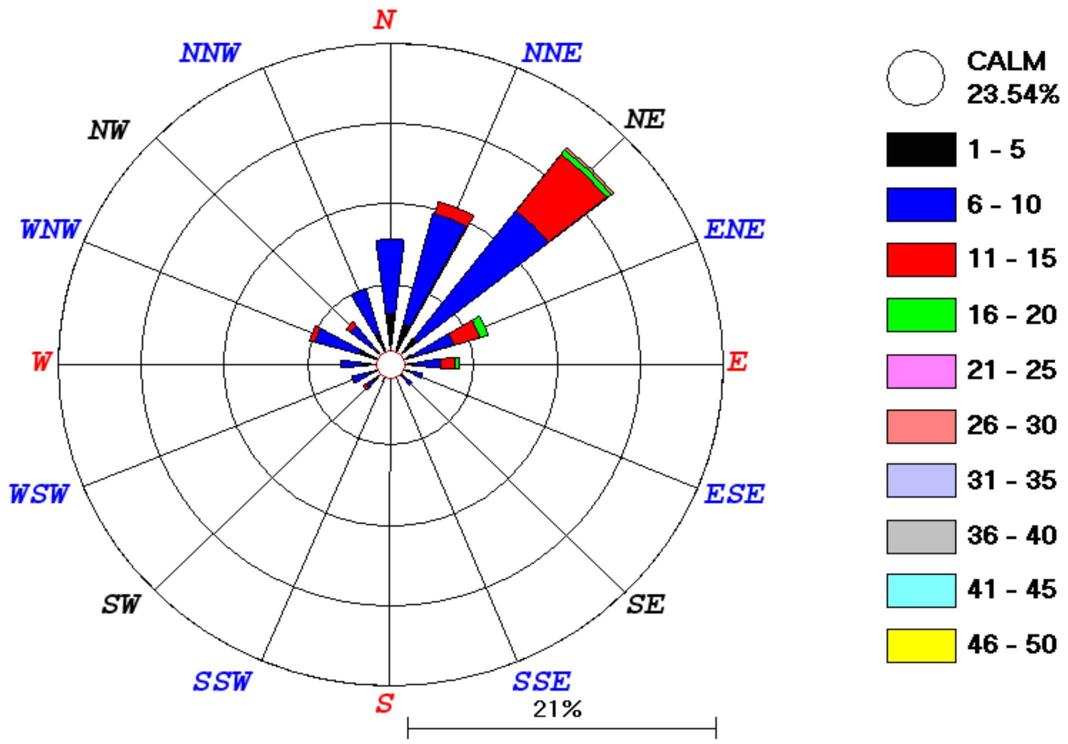


Figure 6: Windrose Diagram of Kerala GIDC – Jan'20 to Feb'20

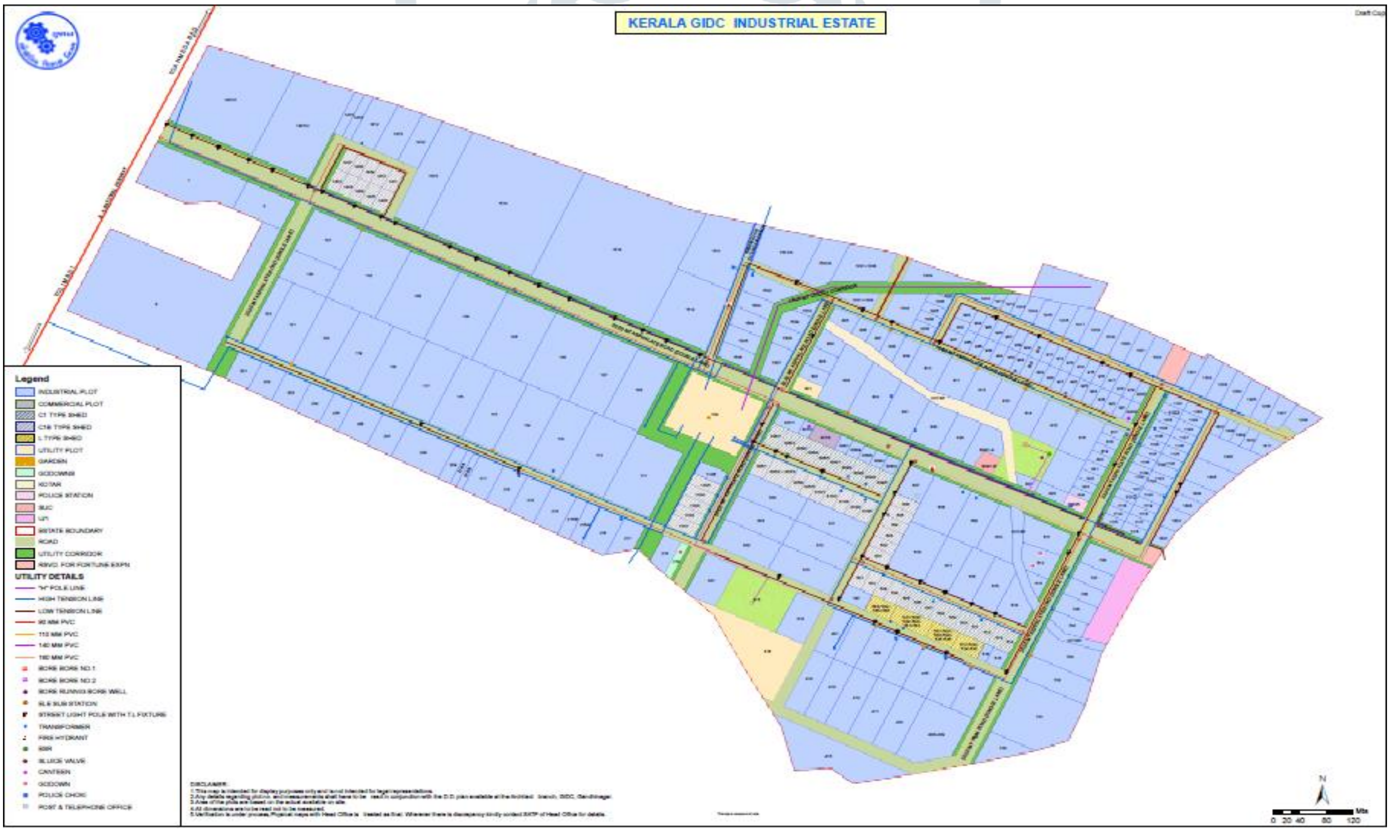


Figure 7: Map of Kerala GIDC

VI. VISIT OF THE STUDY AREA

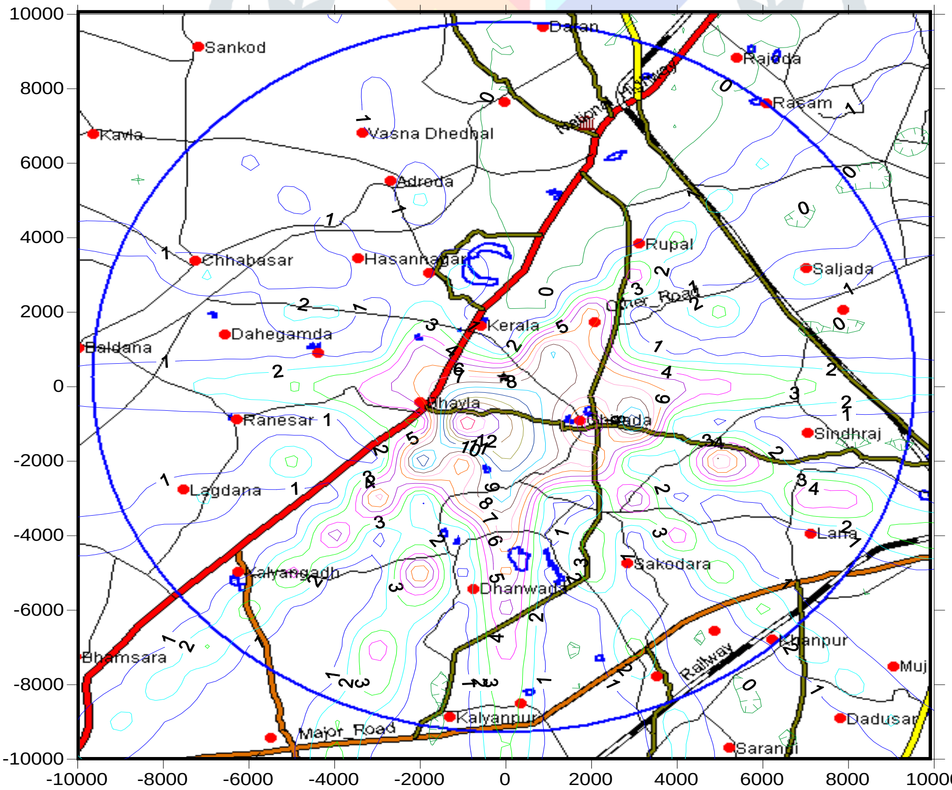
The major sectors of industries found in the study areas are Oil Ginning / expelling, pharmaceuticals, printing (gravure / digital), pesticides, food & food processing, synthetic resins, steel / iron products, yarn / textile, organic / inorganic chemical, vegetable oil, common treatment facility etc.

Figure 8: Industries of Kerala GIDC Industrial Estate emitting Particulate Matter

For the study, approximately 70 different industries are chosen. From these industries, study is carried out for stacks attached to Boiler for identify actual emission of Particulate Matter from the area. Approximately 60 stacks were found emitting Particulate Matter from such industries. Location of various industries is shown in the figure below. The industries pinned are the sources of Particulate Matter emission. Each industry is having one or more stacks attached to boiler or any other Particulate Matter emission source.

VII. RESULTS AND DISCUSSION

From 60 identified Particulate Matter emitting stacks, approximately 24 nearby stacks were chosen as data input to AERMOD for ease of software run. The input data was given to AERMOD and the dispersion of Particulate Matter was superimposed on 10 km radius map of Kerala GIDC.



1	2	3	4	5	6	7	8	9	10	11	12
0-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90	91-100	101-110	111-120

Figure 9: Dispersion of Particulate Matter superimposed on 10 km radius map

In the above figure, the dispersion of Suspended Particulate Matter is seen throughout the 10 km radius area. As shown in the figure, emission resulted from various stacks of various industrial units of Kerala GIDC is visible throughout the 10 km radius map. The greater the distance is, the lesser the pollutant concentration. The above figure indicates that the concentration of

Particulate Matter is highest in the center, i.e. within the GIDC area. With increase in distance from the center of GIDC, the pollution potential decreases gradually. In the above figure, various colored lines are shown, each showing different number with different color. In middle of the figure, the highest numbered lines are visible, which decreases gradually with distance from center, indicating the decrease in the Particulate Matter concentration. The concentration of pollutant decreases gradually as we move from 12 to 1 as shown in the above figure. The scale for various colored lines is also shown above.

The cumulative concentration of Particulate Matter obtained after meteorological as well as emission data input for the months of January and February, 2020, the AERMOD gave following results:

Sr. No.	Month	PM concentration (µg/m^3)
1.	January – 2020	77.1
2.	February – 2020	68.6

Table 1: Stack Emission Quality and AERMOD input

- **VALIDATION WITH HIGH VOLUME AIR SAMPLER**

The results of AERMOD was validated with the results of High Volume Air Sampler (HVAS) for concentration of particulate matter (PM_{10}).The High Volume Air Sampler (HVAS) was placed at three locations of Kerala GIDC as mentioned below:

1. Near the entrance of GIDC
2. At the distance of approximately 800 m from the entrance
3. On the terrace of the unit, approximately 1.5 km from the entrance

The sampling was carried out for three times for 8 hour averaging period during the months of January and February, 2020. The results obtained after following the standard sampling procedure for the field measurement using HVAS is as follows:

- **RESULTS OF HIGH VOLUME AIR SAMPLER**

S. N.	LOCATION	NAAQS for PM, µg/m^3	PM CONCENTRATION, µg/m^3		
			01.01.2020	12.02.2020	21.02.2020
1.	Near the entrance of GIDC	100	70.50	75.00	73.00
2.	At the distance of approximately 800 m from the entrance	100	69.00	65.30	72.00
3.	On the terrace of the unit, approximately 1.5 km from the entrance	100	70.50	67.50	69.50

Table 2: Stack Emission quality and AERMOD Input

- **VALIDATION**

After obtaining results from AERMOD and High Volume Air Sampler, the comparison of concentration of particulate matter is as follows:

	January, 2020	February, 2020
AERMOD	77.10	68.60
HVAS	70.00	70.38

Table 3: Comparison of AERMOD and HVAS

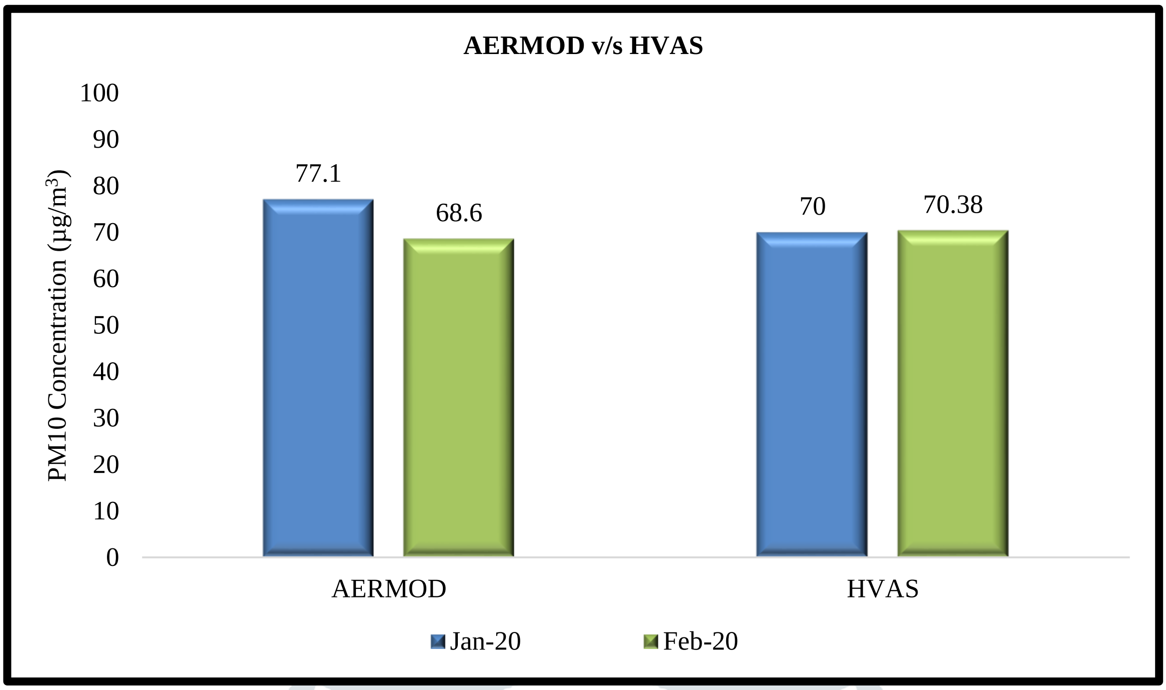


Figure 10: AERMOD v/s. HVAS

VIII. CONCLUSION

Based on the study carried out, following conclusions shall be derived:

- The assessment of cumulative particulate matter of Kerala GIDC, Ahmedabad for the radius of 10 km is done successfully using AERMOD model.
- The assessment of particulate matter (PM_{10}) is done for the months of January and February, 2020 using AERMOD.
- The results obtained for the particulate matter using AERMOD are 77.1 µg/m^3 and 70µg/m^3 for the months of January-2020 and February-2020 respectively.
- The assessment of particulate matter of Kerala GIDC, Ahmedabad using AERMOD showed the tendency to reach ground level near to the source of emission under low wind conditions; however it may show its impact up to 10 km radius.
- The result obtained from AERMOD is compared with the results of High Volume Air Sampler (HVAS) for field measurement of particulate matter (PM_{10}).
- The High Volume Air Sampler was placed at three locations for the same respective months of January-2020 and February-2020 and the results obtained are 68.6µg/m^{3}and 70.38 µg/m^{3}respectively.

The study showed that the results of AERMOD and HVAS are almost similar and the particulate matter concentration of Kerala GIDC is within limit, as per National Ambient Air Quality Standards (NAAQS), i.e.100 µg/m^3 for the monitoring period of January and February 2020.

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