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SPM Assimilative Capacity Assessment of Mundra Taluka

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Abstract

After the devastating earthquake in 2001, Central and State government have provided various incentives for rapid economic development of Kutch district. Mundra, one of the taluka of Kutch District, located on the bank of Northern Gulf of Kutch, having Mundra Port & Special Economic Zone, also witnessed the rapid industrial growth after 2001. Due to ease in import of raw materials and export of finished goods industries like Steel, Low Ash Metallurgical Coke, Steel pipes, Power Plants, Oil refineries and port base storage terminals have come-up in the region. All this economic developmental activities have put stress on quality of air environmental. For further systematic and planned development of the region there was a need to assess the air assimilative capacity of the region i.e. the further air load a region can sustain. In the present paper SPM assimilative capacity of Mundra taluka is determined by utilizing air quality modeling (ISCST-3) as a tool to determine the maximum allowable concentration and in turn maximum emission load, that a region can assimilate without violating the stipulated NAAQS.

1. Introduction

Carrying capacity in context of industrialization can be defined (Subramanium, 1998) as the "Maximum Industrialization a region can sustain at maximum rate of resource consumption and waste discharge that can be sustained indefinitely in a defined region without progressively impairing the bio-productivity and ecological integrity of the region." Thus carrying capacity is a trade off between the supportive capacity and assimilative capacity (Singal, 2009). Defined in the context of carrying capacity of air environment, it is the maximum amount of air pollution load that can be discharged without violating the best designated use of air resource in the planning region. The phenomena governing the carrying capacity of air environment include dilution, dispersion and deposition.

The operational framework for estimation of carrying capacity of any region (NEERI, 2001) Involves the following:

- Estimation of Existing Pollution Load
- Estimation of Assimilative Capacity
- Estimation of Supportive Capacity

In the present study Carrying Capacity of Mundra Taluka in the context of Suspended Particular Matter (SPM) has been estimated.

2. Methodology

Methodology adopted for estimation of SPM carrying capacity of air environment involves:

1. Delineation of air shed based on topography of the area and identification of micro-climatic zones depending upon topography and wind field data;
2. Preparation of Air Pollution load inventory for point, area and line sources and quantification of air pollution load;
3. Measurements of the on-site Meteorological Data;
4. Prediction of Ground Level Concentrations (GLCs) of SPM for the existing sources using Multiple Source-Receptor ISCST-3 Model;

5. Estimation of available Assimilative Capacity in the region based on the National Ambient Air Quality Standards; and
6. Estimation of Supportive Carrying Capacity i.e. supportive load in the region based on assimilative capacity & the existing pollution load.

3. Study Area

For the present study, the study area selected was Mundra taluka, located in the east of Kutch District in the State of Gujarat. Mundra taluka is surrounded by Gulf of Kutch in South-East, Mandvi taluka in North-West and Anjar –Bhuj taluka in North-East directions. Mundra taluka is also having India's largest private port i.e. Mundra Port located on the bank of Northern Gulf of Kutch. Map of Mundra taluka is attached a Figure 1.

After devastating earthquake in 2001, Central and State Government have provided various incentives in the Kutch District, to promote rapid industrial and economic growth of the District. Because of this, rapid industrial development has been witnessed in Mundra taluka after the year 2001. Secondly because of development of Mundra Port, logistics in terms of Import – Export have become more feasible in Mundra. New SEZ i.e Mundra Port & Special Economic Zone (MPSEZ) has been sanctioned in Mundra region. Due to all these reasons Mundra has become an industrial hub for various industries like steel, coke, plywood, steel pipes, oil refineries, port base storage terminals and power projects.

Mundra taluka is spread over an area of 888.2 Km^2 with a total population of 90456 persons, and population density of 93 persons per sq. km. Transportation and other infrastructure facilities are not very well established in the region.

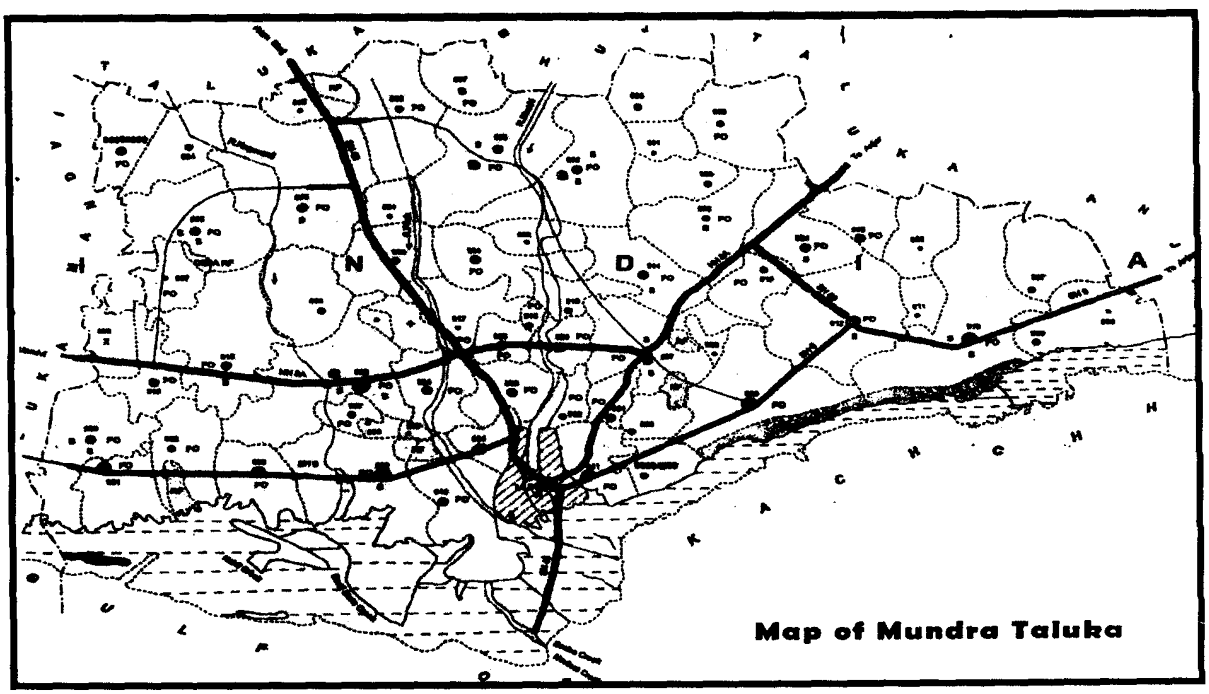

Figure 1: Map of Mundra Taluka

4. Pollution Load Inventory

As per the US-EPA-1981, the inventory is ideally a "Comprehensive, accurate and current accounting of pollutant discharges and associated data from sources within the inventory area over a specific time interval". Pollution inventory gives us rapid and comprehensive assessment of industrial waste load existing in an area.

The total SPM load in the study area from the Industrial, Domestic, and Vehicular Sources is represented in Table 1. Industrial Sector is the major contributor to the total air pollution load in the study area (91%), followed by domestic sector (7%) & vehicular sector (2%).

Table 1: Total SPM Emission Load in Mundra Taluka (Kgs / Day)

Sr. No.	Sector	SPM Pollution Load (Kg/Day)
1	Industrial	5444.03
2	Vehicle -Highway	109.27
	Vehicle- Internal	11.55
	Total Vehicular Load	120.82
3	Domestic	418.39
	Total	**5983.23**

4.1 Industrial Air Pollution Load

The main sources of SPM emissions from industrial sectors are:

1. Flue gases: combustion of fuels for heating & power requirement.
2. Fugitive Emissions: dust and gases from industrial process & material handling.

In the Mundra region there are about 30 nos. of polluting industries (both large and medium scale). For estimation of SPM air pollution load, source characteristics data were collected from the Air Consent granted to the industries under the "Air Act- 1974" by the Gujarat Pollution Control Board. The following data were collected: Stack height (m), Stack diameter (m), Stack exit gas velocity (m/sec), Stack gas temperature (°K), Types of pollutant emission and emission limit (mg/Nm^3). Total SPM load from industrial sector works out to be 5444.03 Kgs/day.

4.2 Vehicular Air Pollution Load

In order to assess the total vehicular emission load, the transport network in the region has been divided into two parts:

(a) Vehicular emission load due to traffic movement on Major Traffic Corridors (Highways):
Major Traffic Corridors were identified in the study area and Traffic Survey was carried out. Link wise equivalent Passenger Car Units (PCU's) were calculated on highway corridors. Highway corridor length and width were measured. The Pollution load was estimated for each traffic corridor, and is shown in Table 2.

Table 2: Estimated Vehicular Emission Load due to Highway Traffic

Name of Road	Type of Road	Width (m)	Road Length (Km)	Traffic in PCU's	SPM Load (Kg/day)
Mundra to Bhuj	S.H.	7	25	3102	45.15
Mundra to Anjar	S.H.	7	25	7290	41.71
Mundra to Mandvi	N.H	7	26	6024	22.41
				TOTAL	**109.27**

(b) Vehicular emission load due to internal local traffic movement:
Total number of vehicles registered by the Bhuj RTO till March 2009, was collected and approximate number of vehicles in Mundra talukas was estimated. The Pollution load was estimated considering the No. of Vehicles (Nos./Day), Emission Factor (gm/KM) and Origin-destination Distance(Km), and the same is shown in Table 3.

Table 3: Estimated Vehicular Emission Load due to Internal Vehicular movement

Nos. of Vehicles					SPM Load (Kg/day)
LCV	3 Wheeler	Car	2-Wheeler	Bus	
1452	385	2123	15337	33	11.55

4.3 Domestic Air Pollution Load
Domestic fuel emissions are another major air pollutant quite common to both rural and urban areas. In rural areas Fire wood, Biogas/ Dung Cake, saw-dust, waste-paper or any sundry waste are the common fuels. In urban areas Liquefied Petroleum Gas (LPG), Kerosene and Firewood are the major fuels. Pollution load from burning of fuel in domestic sector is calculated as based on Fuel Consumption and Emission Factor from WHO Publication No. 62. Total SPM load from domestic sector works out to be 418.39 Kg/day.

5. Air Quality Modeling
Modeling on a macro scale gives the predicted Ground Level Concentrations (GLCs) due to combined effect of distributed Point, Area and line sources of emissions. The models consider the effect of region specific meteorological conditions and emission loads on dispersion and diffusion and dilution of the air mass.

For the present study, prediction of GLCs of SPM was carried out using the USEPA approved ISCST-3 simulation model: The following assumptions (User's Instructions, EPA-454/B-95-003a, 1995a,b) were made in the modeling exercise:

- The study area was Mundra Taluka having an area of 888.02 Km^2. This area was further subdivided into smaller grids of 4000 x 4000 m. Size.
- The industrial complexes were identified in the map with respect to the bottom left corner, which was considered to be the origin (0.0) for modeling the study area. Fig is attached as a Figure No.2.
- The mixing height based on the CPCB publication "Spatial Distribution of hourly mixing depth over Indian Region" probes / 88/2002 -03 has been considered.
- A pollutant concentration was predicted for a receptor grid size of 1000 m x 1000 m.

5.1 Pollution Sources
Various sources in the study area that may be responsible for SPM at the receptor point can be divided in to point, areas and line source.

Point Sources
All industrial emissions are considered as point sources. All the stack gas emissions were divided in to three categories:

1. Stack gas emissions from Tall stacks (more than 60 m)
2. Stack gas emissions from Medium stacks (between 60 to 30 m)
3) Stack gas emissions from Small stacks (less than 30 m)

Area Sources

Domestic & Vehicular emissions were considered as area source emissions. The vehicular emissions are considered as Area source emissions, as the Mundra taluka has very low vehicular density and in turn vehicular emission load, and in the absence of detailed internal road & traffic network analysis, the vehicular emissions were considered as Area Source for ISCST Modeling.

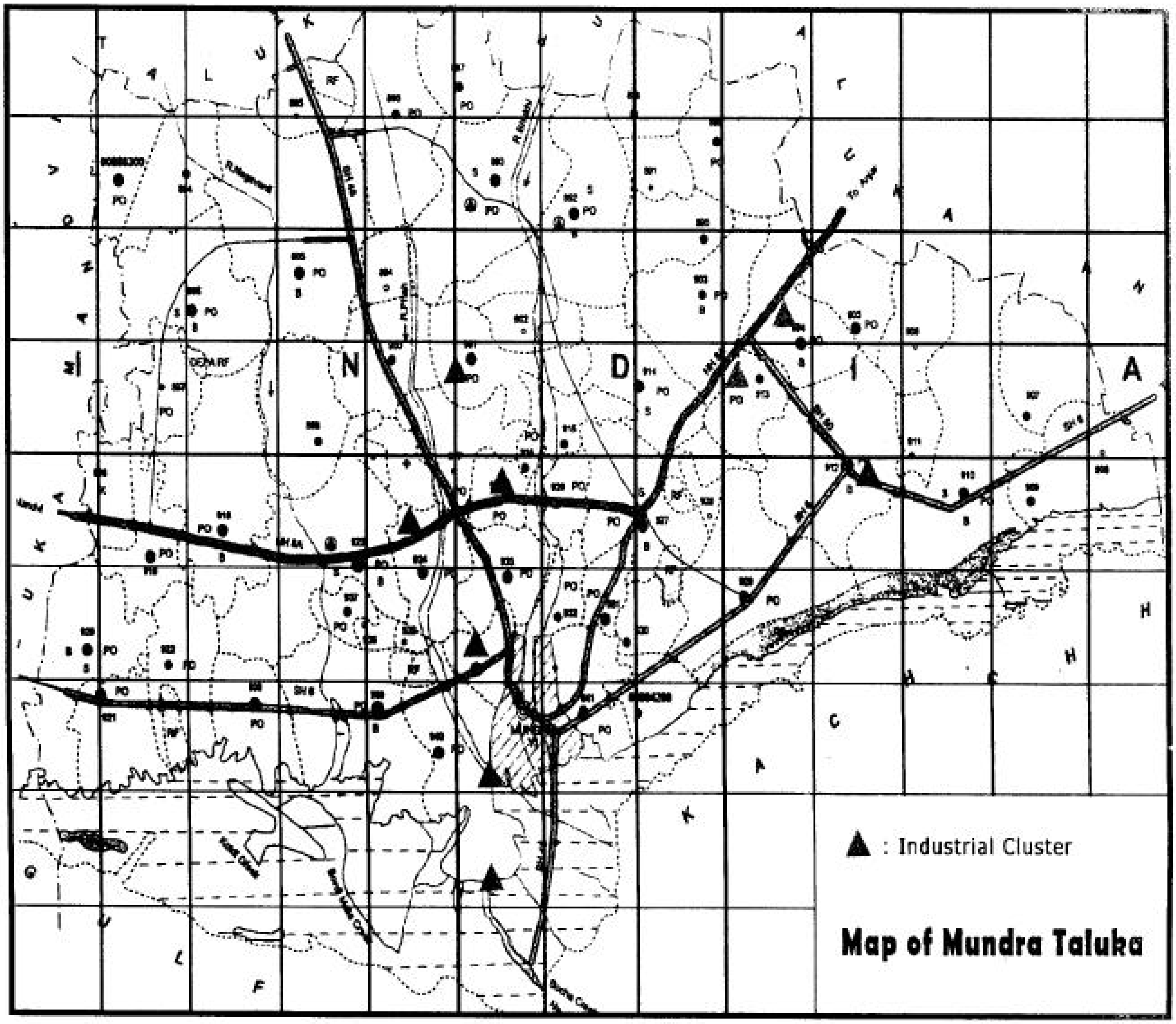

Figure 2: Pollution Source Co-ordinates in the Study Region

5.2 Meteorology

Meteorological conditions of the Region regulate the transport and diffusion of air-pollutants released into the atmosphere. Meteorological data for Mundra Taluka for parameters namely, ambient temperature, wind speed, wind direction, relative humidity and stability class were collected by using Wind Monitor - WM 300 instrument at an hourly interval for the period of March 2009 to May 2009. The monitoring station was set-up at Village Samaghogha , Taluka Mundra. The wind rose diagram is presented at Figure 3. As specific mixing heights were not available, mixing height based on CPCB publication "Spatial Distribution of Hourly Mixing Depth over Indian Region", PROBES/88/2002-03 has been used.

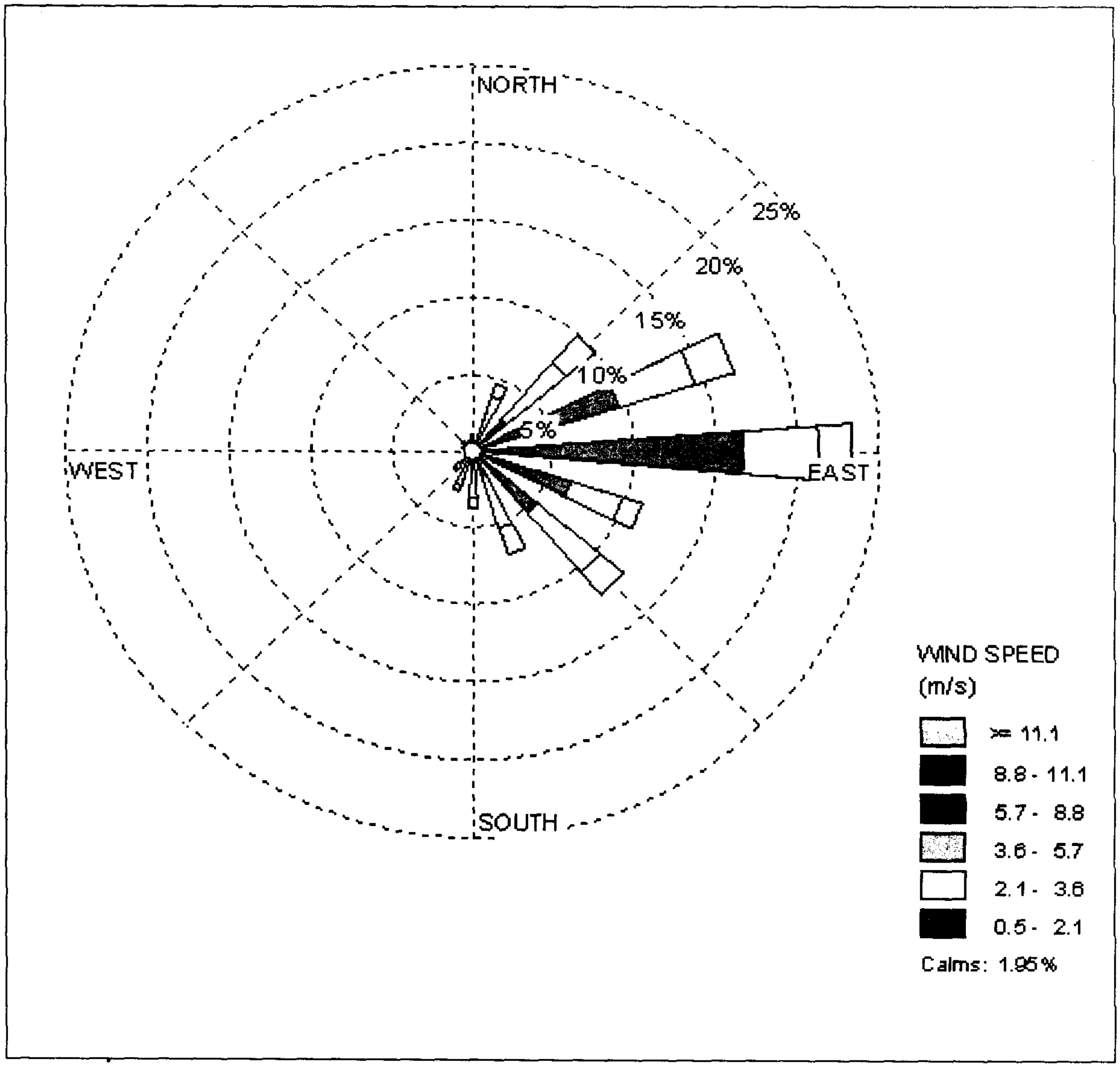

Figure 3: Mundra Taluka Windrose Diagram

5.3 Results of the ISCST-3 Model

Two separate model runs were carried out for point and area sources to determine the predicated SPM ground level concentrations. The output results were obtained in the grid of 1000 x 1000 m. The cumulative average Ground Level Concentrations (GLCs) were determined. The cumulative Isopleths of SPM concentration from point and area source are shown in Figure 4. The cumulative predicted maximum average 24 hourly concentrations for SPM is 55 $\mu g/m^3$.

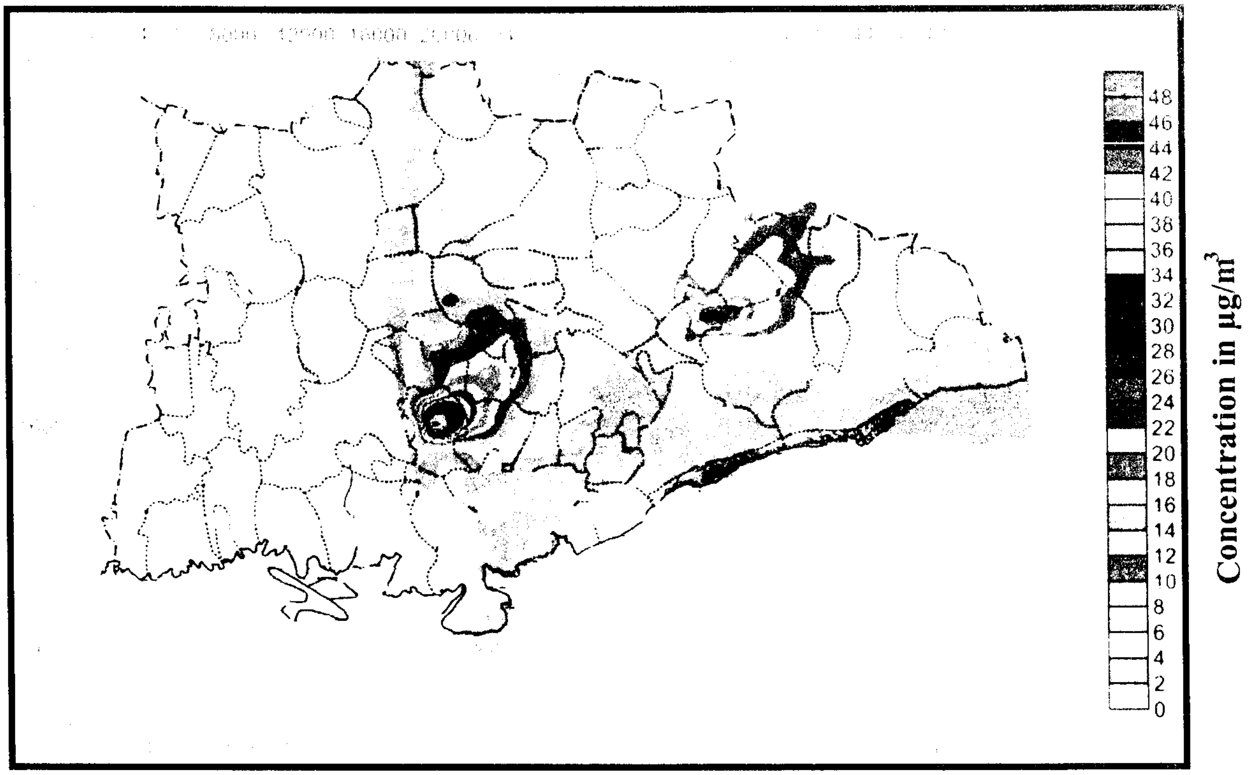

Figure 4: Isoplaths of SPM Concentration for 24 Hours

6. Assessment of Air Carrying Capacity

Assimilative capacity of Air Environment is the maximum amount of air pollution load that can be discharged in to the atmosphere without violating the best designated use of the air resource in the region (Manual MoEF, New Delhi). The phenomena governing assimilative capacity of air environment includes dilution, dispersion and deposition. The assimilative capacity of the region needs to be assessed, suitable approach has to be carefully selected and adequate plans need to be prepared so that the receiving environment is least affected. Ventilation coefficient approach and modeling approach have been applied to study the assimilative and carrying capacity of the region.

6.1 Ventilation Coefficient Approach

The air pollution assimilative potential of an air shed can be estimated as the ventilation coefficient for the area. The ventilation coefficient is an indicator of horizontal as well as vertical mixing potential. Ventilation Coefficient (VC) is determined by multiplying the mixing height and the mean wind speed through the mixing air. The National Environment Engineering Research Institute (NEERI) in 1990 has divided India into nine types of zones based on ventilation coefficient. The Kutch region was found to be in the range of 6000-8000 m^2s^{-1}, which falls under medium pollution category from air pollution dispersion point of view.

However, a critical review of assimilative capacity based on ventilation coefficient approach is found to simply present the dispersion behavior of pollutants in different seasons. The actual emission load that can be assimilated in the region in absolute quantitative terms can not be estimated i.e., VC does not give any idea about the amount of emission load that can be assimilated in the region. Thus since ventilation coefficient only provides a broad indication of the dispersion potential, i.e., low, medium or high of the region, therefore, a modified approach for estimation was considered to be applied.

The modified approach was based on actual air quality surveillance monitoring. It uses the maximum pollutant concentration and emission load from different sources along with pollution potential to assess the assimilative capacity of the air environment. This approach of estimation of assimilative capacity is formulated keeping in view the very definition of assimilative capacity.

Assimilative capacity (Singal, 2009) depends on a variety of environmental parameters like

- Meteorological conditions
  viz. wind speed, wind direction, temperature, mixing height
- Terrain characteristics
  viz., plane, hilly, coastal
- Emission characteristics
- Type of emissions, viz. industrial distribution of emission sources, stack characteristics, emission load, vehicular speed, type, road length, emission loads, domestic type of fuel, population.

6.2 SPM Assimilative Capacity Estimation

In the present study, the assimilative capacity of Mundra Taluka was estimated based on the modified approach. The volume of air shed considered was 888.2 Km^2 x 0.150 Km. The study was carried out for the summer season.

The discharged emission load at which the maximum allowable concentration (i.e. NAAQ) was reached is considered as the assimilative capacity of the region. In India, the National Ambient Air Quality Standards (NAAQS) have been stipulated based on the land use, primarily under industrial, mixed use (residential/commercial rural) and sensitive areas category (CPCB, 1994). For the present study, the NAAQS for SPM has been considered as the study region is not a notified sensitive area and the industrial area limits are not relevant. Moreover, exclusive industrial area had not been clearly defined in the region and the residential areas are mixed with industrial areas.

Based on the maximum allowable concentration (i.e. NAAQS), the allowable emission load (i.e. assimilative load) was calculated for the said air shed assuming that the pollutant disperse up to 150 m height in the atmosphere since most of the stacks in the region were observed to be above 30 to 80 m height. The maximum allowable concentration and the assimilative emission load in the region are summarized in Table 4.

6.3 SPM Supportive Carrying Capacity Estimation

The difference between the maximum allowable concentration for a given area and the present average ambient concentration in that region gives an indication of the amount of supportive carrying capacity of the region. The positive value shows the availability of additional, load, while negative values show that excess load is already present in the area. In case of negative values, there is no question of any additional air pollution load in the region. Rather, the area requires the adoption of the most stringent abatement and control measures.

The present average ambient concentration in the region was estimated through ISCST modeling. Since the 24 hourly averaged NAAQS for SPM is 200 $\mu g/m^3$ and the maximum predicted GLC from ISCST Modeling for SPM is 55 $\mu g/m^3$, these give us the available increment of 145 $\mu g/m^3$. For this available increment, the maximum permissible load or supportive load of the region was calculated. The calculated SPM supportive capacity is shown in Table 4.

Table 4: Carrying Capacity Estimation of Mundra Taluka

Parameter	NAAQS ($\mu g/m^3$)	Max. GLC from ISCST Model ($\mu g/m^3$)	Assimilative load (Kg/day)	Max. Supportive Incremental Concentration ($\mu g/m^3$)	Supportive Load (Kg/Day)
SPM	200	55	26554.50	145	(+Ve) 19318.35

6.3 Pollution Intensity

Pollution Load Intensity, in terms of Pollution Load in Kg per Sq. Km area was also calculated. It is defined as the pollution load in the study zone per unit area of the study zone. Thus higher is the pollution load, more will be the pollution intensity. Pollution load has been estimated in terms of industrial, vehicular and domestic pollutions. It has been presented in Table 5 as also graphically depicted in Figure 5.

Table 5: SPM Pollution Intensity in Mundra Taluka

Sources of SPM Emissions	Pollution Load (Kg/Day)	Pollution Intensity (Kg/Km^2)	Assimilative Intensity (Kg/Km^2)
Industrial	5444.03	6.15	30.00
Vehicular	120.83	0.14	
Domestic	418.39	0.47	
TOTAL	**5983.23**	**6.76**	

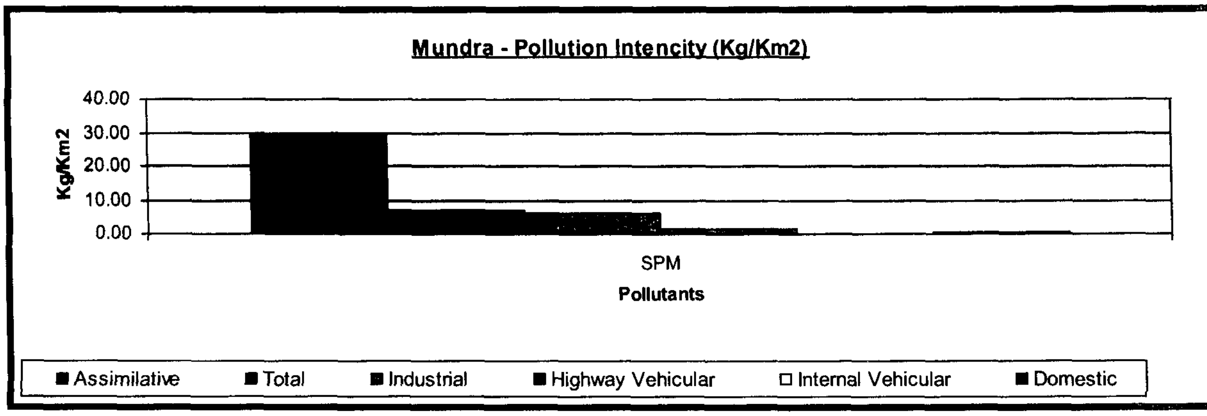

Figure 5: Pollution Intensity in Mundra Taluka

The SPM pollution intensity due to SPM emissions in Mundra taluka due to Industrial, Vehicular and Domestic emissions is low compared to SPM assimilative intensity of Mundra Taluka.

7. Conclusion

Industrialization has become an instrument for economic growth of the Mundra Talluka, however, at the same time stress has been put on the existing resources and quality of surrounding environment. In the present study SPM carrying capacity of Mundra taluka was assessed with the help of pollution load inventory and air quality model ISCST-3.

The existing SPM pollution load was calculated for Industrial, vehicular & domestic sources. The total estimated existing SPM pollution load in the region works out to be 5983.23_Kg/day. The ISCST-3 model run was carried out for point and area sources of emissions. The maximum predicted cumulative 24 hourly ground level concentration of SPM was 55$\mu g/m^3$. Considering NAAQS for SPM of 200$\mu g/m^3$ as the allowable assimilative concentration in the region, the assimilative load works out to be 26554.50 Kg/day. The SPM supportive capacity was estimated by the difference between the allowable concentration i.e. 200 $\mu g/m^3$ and predicted maximum GLC of 55 $\mu g/m^3$. This gives us the available maximum increment of145 $\mu g/m^3$. For this available maximum supportive increment, the maximum supportive load works out to be (+ ve) 19318.35 Kg/day.

2. Methodology

2.1: Study Area

Burla is the most important town in western part of Orissa and is about 16 km away from Sambalpur. It is located at 21° 30' 0" N latitude and 83° 52' 0" E longitude at 173 m above MSL. Burla experiences temperate climate throughout the year. The area is blessed with rainfall from the South West monsoons and receives average annual rainfall of about 152.7 cm. The monsoon season in Sambalpur stretches on from July to September and experiences high humidity levels. In summers, the temperature ranges from 24.2 degree centigrade (minimum) to 44 degree centigrade (maximum). At times, the maximum temperature shoots to as high as 46 degree centigrade. During winters, the temperature is between 11.5 (minimum) and 28.5 degree centigrade (maximum). It may drop down to as low as 8 degree centigrade also. As of 2001 India census, Burla had a population of 39,188. During the periods, population of Burla has increased many manifolds due to various activities. Mahanadi Coalfield Ltd. (MCL) has established two large residential complexes having 1000 population in each campus at Burla. One of its campuses, named Jagruti Vihar having 202 dwellings along with its Corporate Office and Guest Houses etc. is situated adjacent to National Highway (NH)-6 and hardly 100 m away from Hirakud railway station.

NH-6 has a heavy transaction of both heavy vehicles and light vehicles during high peak hour and also considerable amount of vehicles pass during low peak hour. Plying of different categories of vehicle contributes to air pollution and results in the deterioration of environment quality of the air. Besides the loading and unloading activities at Hirakud railway station compounds the problem. In view of close proximity to NH and railway station, it was thought to gauge the deterioration of air quality inside the campus due to plying of vehicles on NH-6 and railway siding area. For the present study, a short-term survey was planned at three representative sites. The study area along with monitoring locations (P_1, P_2, and P_3) is shown in Figure 1. Three sampling points were chosen one near the gate (P_1) i.e. 10 m from NH, another nearly 200 m from NH (P_3), and third one nearly 350 m from NH (P_2).

2.2. Monitoring Instrument

At each monitoring site, the concentration of PM_{10} was measured. Respirable dust sampler (Envirotech) was deployed for the monitoring of ambient PM_{10}. TSP was also measured to estimate PM_{10} fraction in TSP. Ambient air laden with suspended particulates enters the respirable dust sampler through inlet pipe. As the air enters the cyclone, coarse, non-respirable dust is separated from the air by centrifugal forces acting on the solid particles. These coarse particulates fall through the cyclone and get collected in the sampling bottle fitted at its bottom. The air stream passing through the filter paper, which was clamped between the top cover and filter adopter assembly, carries the fine dust forming the respirable fraction (PM_{10}). The concentration of TSP and PM_{10} were estimated from filter paper and dust collected in the cyclone cup. The instruments were operated at a flow rate of 0.90–1.15 m^3/min. Monitoring of PM_{10} was carried out once a week for a period of 24 h at each monitoring site.

2.3. Sample Analysis

From the PM_{10} collected on 20.3 x 25.4 cm Whatman quartz microfibre filters, the particulate mass concentrations were measured gravimetrically by weighing the collected particles and knowing the total volume of air sampled. Sum of total mass collected on filter and in cyclone cup was considered as TSP. Filter papers were kept in a desicator for 24 h before and after the sample collection. Field and laboratory blank filter samples were routinely analyzed for PM_{10} to evaluate analytical bias and precision. It is assumed that the PM_{10} deposited on quartz micro-fibre filter papers were uniformly distributed over the entire area.

After gravimetric analysis, a known portion of the exposed filter paper sample was extracted for trace metals (APHA, 1977). The quartz microfibre filters were digested in HNO_3 (nitric acid). The digested solutions were then analyzed by using inductively coupled plasma atomic emission spectroscopy (Jobin Yvon JY-24) for heavy metals. An intensive quality control program was implemented to maintain the accuracy and precision throughout the study.

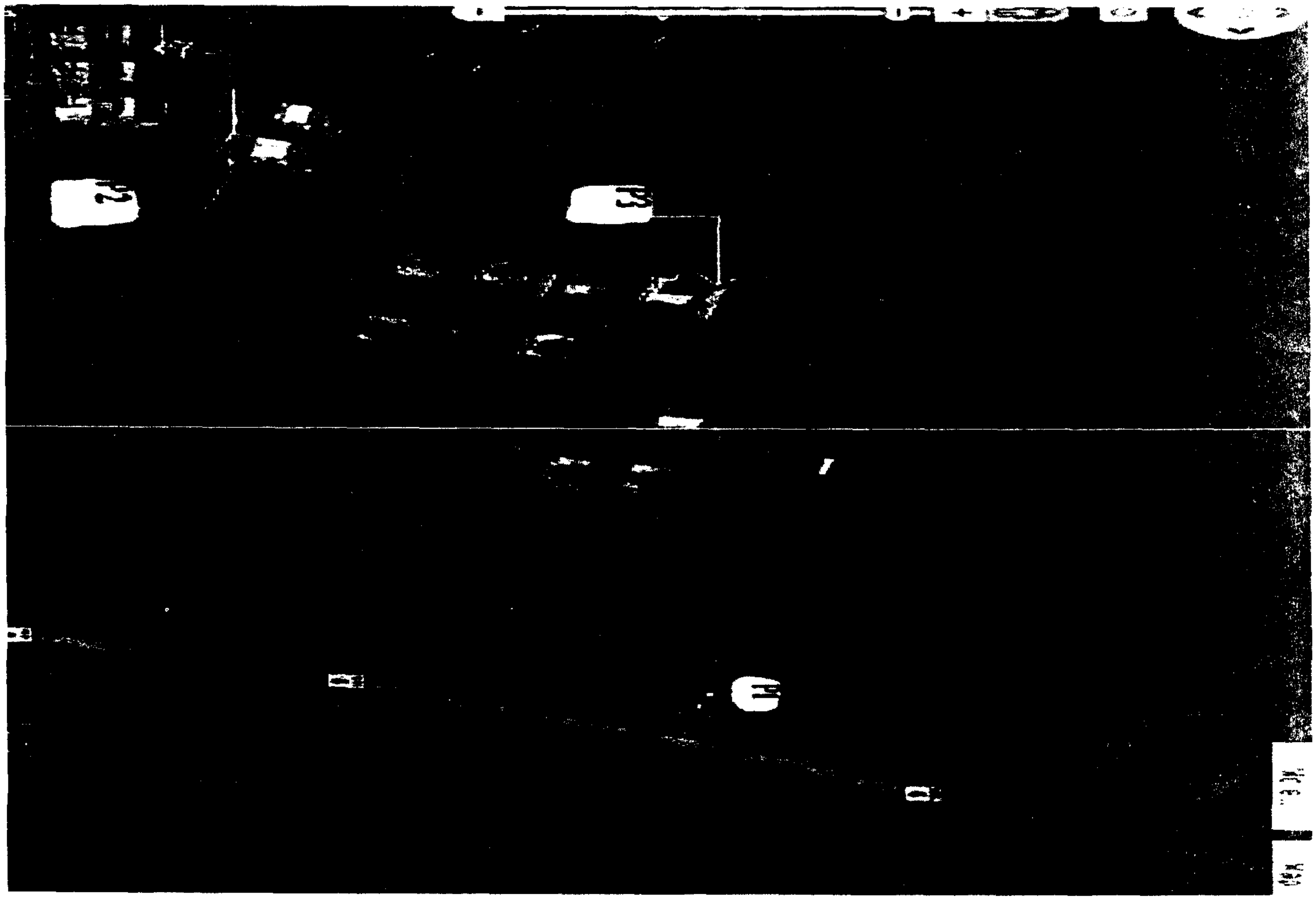

Figure 1: Monitoring Locations of the Study Area with Major Line Source Locations

3. Results and Discussion

During the study period, 24 h average PM_{10} levels was in the lowest concentration range (64-83 μg//m^3) at the farthest location (P_2) and 112- 212 μg//m^3 at the gate (close to NH 6 and Railway station i.e. P_1). Table 1 shows the PM $_{10}$ levels in ambient air within residential campus for the study period and Figure 2 indicates a comparison between TSP and PM_{10}. The average PM_{10} concentration at the gate was around 2.0 times higher than the farthest site. High particulate concentration at Gate may be attributed to the heavy vehicular traffic flow, and re-suspension of road and soil dust. Other sources of particulate matter in the study area that might affect the PM_{10} distributions are gas-to-particle conversion processes favoured by the relative humidity. Further, 24 h average PM_{10} levels was in higher concentration range in the month of April than March at location P_1 and P_3. It may be due to increased loading and unloading activities at Railway station in April.

At each monitoring site, 08 sets of daily average PM_{10} samples were collected during the study period. Daily average PM_{10} concentrations exceeded the value of National Ambient Air Quality Standard (NAAQS) as specified by Central Pollution Control Board (CPCB), 08 times at the gate (P_1), and 03 numbers of times at the station (P_3). The 24 h average NAAQS for PM_{10} at the residential area is 100 μg/m^3. 100 % of the monitored PM_{10} data at the Gate and 38 % at the middle station (P_3) exceeded NAAQS (CPCB, 1998). The high value of particulate pollution at the residential site may be due to plying of vehicles on NH 6 and loading & unloading activities at Hirakud Railway Station.

The above shows that Mundra Taluka has further SPM Supporting Carrying Capacity and can further support industrial growth. Moreover, SPM pollution intensity i.e. Pollution load per Sq. Km works out to be 6.76 Kg/Km^2, which is far below the assimilative pollution intensity of 30 Kg/Km^2.

It is thus concluded that there is scope for further industrial development in the Mundra region. However, at the same time, the large development would obviously have environment thrust and hence necessary environment resource planning ought to be done for sustainable development.

Acknowledgements

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