An Assessment of Assimilative Capacity, the Current Industrial Air Pollution Load and Supportive Carrying Capacityin the Chakan Region

Kalyani N Kulkarni#1, Ravindra K Lad*2
#1Research Scholar, Department of Civil Engineering, RSCOE, Tathawade, Pune, Maharashtra, India
*2 Research Guide, Department of Civil Engineering, RSCOE, Tathawade, Pune, Maharashtra, India
Savitribai Phule Pune University, Pune, Maharashtra, India
1knkulkarni@aissmscoe.com
2ravindraklad5@gmail.com

Article Info
Page Number: 8030 - 8036
Publication Issue:
Vol 71 No. 4 (2022)

Abstract
Oxygen is the most fundamental and significant component of life on earth, even before the traditional "food, clothes, and shelter" needs. Due to numerous contaminants, the amount of oxygen in the air is decreasing and occasionally exceeds the assimilative capacity limit of the air, resulting in a variety of physical issues for living things as well as other environmental issues and physiological activities. A complete proof approach must be devised to solve this issue. The severity of the air pollution in Delhi has reached a point where anxiety has given way to panic. The national capital has experienced a significant reduction in temperature during the winter season, but regrettably, air pollution levels in the city are still rising. Both the Delhi University and the nearby city of Noida have "extremely poor" levels of suspended particles in the air. Strong local winds aid in the removal of particles, whereas moisture retains contaminants close to the surface. In the near future, the same situation might occur anyplace in the nation. Metro areas and other rapidly growing urban centers are more at risk. The situation may stay the same intensity level or it may get more or less severe, which makes things unpredictable. It is vital that techniques be developed and a solution be found to deal with this problem.

Article History
***Article Received**: 25 March 2022*
***Revised**: 30 April 2022*
***Accepted**: 15 June 2022*
***Publication**: 19 August 2022*

Keywords: assimilative capacity, air pollution load, potential, intensity, inventory

Introduction:

The degradation of the natural environment is mostly brought on by ever-increasing pollution levels. The regulatory authorities' permitted limitations permit the emission of restricted air pollutants into the environment. The ever-increasing pollutant load in an ambient, however, is a severe worry because an ambient has a fixed limit. Emitting air pollutants within pollution limits without sufficient dilution also contributes to overall environmental damage. If there are several criteria, both qualitative and quantitative in form, multiple decision makers, uncertainty and risk, and ambiguity surrounding the decision-making, the problem is said to be complicated and tough.

On the potential combined air pollution load from point, area, and line sources, little research has been documented. In order to consider its impact on an ambient at the moment of ultimate emission, it is necessary to look into this component of the Air Pollution Load Potential. By taking into account the combined effects of all the criteria, the supporting carrying capacity of the air pollution load in the area has not yet been reported. In an effort to determine the region's supportive bearing capacity of air pollution load based on assimilative capacity and an existing air pollution load, a fuzzy model using a fuzzy rule-based system (FRBS) has been attempted. Studies of this nature may be relevant to matters of policy formulation. The carrying capacity of a region is described as "the maximum industrialization a region can sustain at the 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" (Subramaniam, 1998) in the wake of ever-increasing industrialization. As a result, the supporting capacity and assimilative capacity are traded off to determine carrying capacity (Singal, 2009). The highest amount of air pollution load that can be released without going against the best designated use of the air resource in the planning region is known as the carrying capacity of ambient. Dilution, dispersion, and deposition are the phenomena that control the carrying capacity of ambient. The following are part of the operational framework for estimating any region's carrying capacity (NEERI, 2001):

Estimates of the following:

a. Existing Pollution Load;
b. Assimilative Capacity; and
c. Supportive Capacity

The carrying capacity of Chakan MIDC within the framework of SPM has been assessed in the current study.

Methodology:

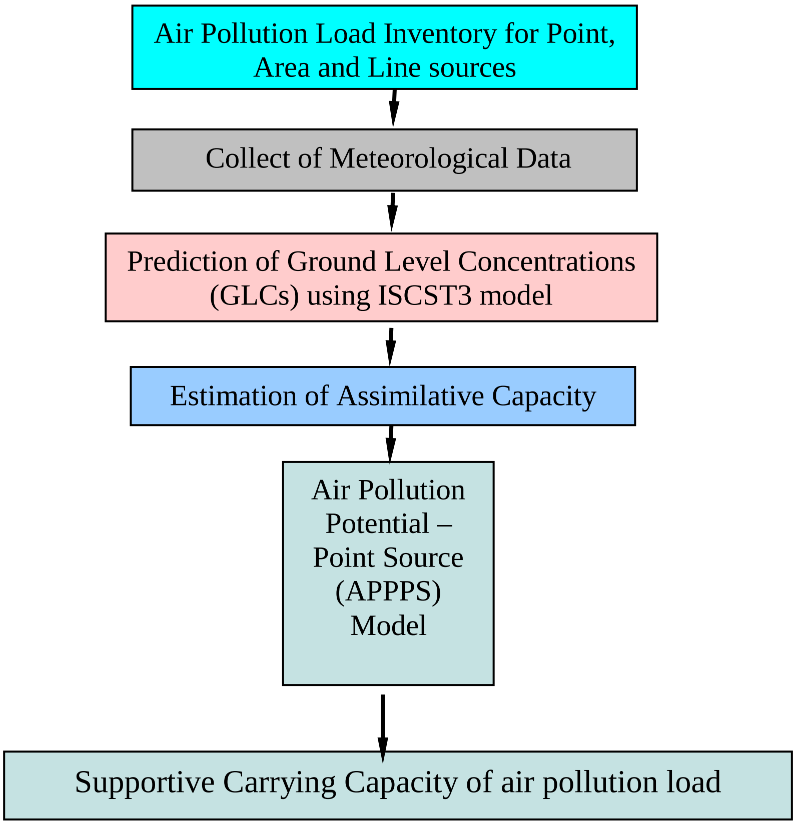
1. Choose a study area
2. Developing an inventory of the air pollution load from all point, area, and line sources, as well as quantifying the load.
3. Compilation of meteorological information
4. GLCs are predicted using the Gaussian Plume equation.
5. Estimation of the region's assimilative capacity based on the NAAQS.
6. Estimation of the region's "supportive load," or "supportive carrying capacity," based on the "assimilative capacity" and the "existing pollution load."

The study highlights air pollution potential due to point, area & line sources and supportive carrying capacity of air pollution load in the region based on assimilative capacity and an existing air pollution load. In the present research, Air Pollution Potential –Point Source (APPPS) model, Air Pollution Potential – Area Source (APPAS) model, Air Pollution Potential – Line Source (APPLS) model, Combined Air Pollution Potential –Point, Area and Line Source (CAPP-PALS) model and Status of Supportive Carrying Capacity of air pollution load (SCCAPL) model will be developed using Fuzzy Rule Based System approach.

The model approach has been explained as under.

Figure 1 Portraysan overview of Fuzzy Decision Framework for an Air Pollution Potential and Supportive Carrying Capacity of Air Pollution Load which is self-explanatory.

The Supportive Carrying Capacity of air pollution load based on air pollution load potential of the sources and assimilative capacity can be approached using Fuzzy Rule Based System approach.



Study Area: Chakan is a census-designated place in Pune, Maharashtra, India. Agriculture still plays a significant role, but the town's industrial growth is rapidly urbanizing the region.

Chakan MIDC Map

A Special Economic Zone (SEZ) supported by the Maharashtra Industrial Development Corporation is now located at Chakan (MIDC). In the 17.1 square kilometer Chakan region, there are 204 large-scale industries, 68 medium-scale industries, and 228 small-scale industries.

Air pollution load inventory for point sources and quantification of air pollution load:

The inventory should be a "Comprehensive, Accurate and Current Accounting of Pollutant Discharges and Associated Data from Sources within the Inventory Area over a Specific Time Period," as per US-EPA-1981. We can quickly and thoroughly assess the industrial pollution load present in a location using pollutant inventories.

The total SPM load in the study area from the industrial, domestic and vehicular sources is given in the following table:

Sr. No.	Sector	SPM Load (Kg/day)
1	Industrial	2446.304

Industrial sector is the major contributor to the total air pollution load in the study area with 76% of air pollution contribution

Industrial Air Pollution load:

The following industrial sectors' primary sources of SPM emissions are:

a.Flue Gases: Fuel combustion for required power and heating.

b.Dust and gases from industrial processes and material handling are fugitive emissions.

As previously noted, there are more than 500 industries (LSI, MSI, and SSI) in Chakan MIDC. Source characteristics data are obtained from MPCB through Consent grants of each industry under the "Air Act 1974" in order to estimate SPM air pollutant load. The following information was gathered: stack height (m), diameter (m), stack exit gas velocity (m/sec), stack gas temperature (deg C), pollutant categories, and emission limit (mg/Nm3). Total SPM load from the industrial sector is calculated to be 24.46 kg/day using the aforementioned criteria.

Air Quality Modelling:

Model is developed for prediction of GLC (Ground Level Concentrations) 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 Gaussian Plume model. And meteorological data collected from Indian Meteorological Department Pune (IMD Pune).

Gaussian Plume equation is given by:

$$X(x,y,z)= \frac{Q}{2\pi\sigma y\sigma z}\ Exp(-\frac{y^2}{2\sigma y^2})[Exp - \frac{(z-H)^2}{2\sigma z^2} + Exp - \frac{(z+H)^2}{2\sigma z^2}]$$

Where,

X(x,y,z) = Concentration of pollutant at the point (x,y,z) in space g/m^3

Q = Source strength ie pollutant emission rate, g/sec

U = horizontal wind speed at the source level (at stack height) m/sec

$H = h + \Delta h$, where, h = Physical height of the stack in (m)
Δh = Plume rise in (m)
H = Effective stack height (m)
Assumptions:

1. The concentrations of the plume in the horizontal crosswind and vertical directions have standard deviations of y and z, respectively, and the plume has a Gaussian distribution in both of these planes.
2. The wind speed at the source level, or the point where dispersion begins, determines the mean speed that affects the plume, which is u.
3. Pollutants are continuously and uniformly emitted at a rate of Q g/sec.
4. Pollutant diffusion in the "x" direction is much less than that in the cross-wind direction. If the emission is continuous and the wind speed is more than 1 m/sec, this is true.
5. At the earth's surface, the plume is completely reflected, meaning that there is no deposition or reaction of contaminants there. Additionally, the contaminants are passive and inert, preventing atmospheric chemical reactions and gravity fallout.
6. Since the variables regulating the pollutant's diffusion are constant in both space and time, steady-state criteria apply.
   The ground beneath the plume is level.

SPM Assimilative Capacity Estimation:
Based on the updated technique, the assimilative capacity of Chakan MIDC is evaluated for the current study region. 292.41 km2 x 0.150 km of airshed volume was taken into account. The survey was conducted during the entire year.
The assimilative capacity of the region is defined as the discharge emission load at which the maximum allowed concentration (i.e., NAAQ) was attained. In India, NAAQS have been established in accordance with land use, especially under the industrial, mixed-use (residential/commercial, rural), and sensitive area categories (CPCB, 1994).
Since the majority of the stacks in the area were found to be higher than 30 to 80 m in height, the permitted emission load (i.e. assimilative load) for the aforementioned airshed was determined based on the maximum allowable concentration (i.e. NAAQS). The following table provides a summary of the region's assimilative emission load and maximum permissible concentration.

SPM Supportive Carrying Capacity Estimation:
The amount of supportive carrying capacity of the region is determined by the difference between the maximum permitted concentration for a certain area and the current average ambient concentration in that location. Positive values indicate that there is room for further load, while negative values indicate that there is already too much weight in the area. Negative values mean that there will definitely be more air pollution in the area. Instead, the region need the installation of the strictest mitigation and control measures.
The model mentioned above was used to estimate the current average ambient concentration in the area. The maximum estimated GLC from the Gaussian Plume model for SPM is 69.59 g/m3, and the 24-hourly averaged NAAQS for SPM is 200 g/m3, therefore this gives us the possible increase

of 20 g/m3. The region's maximum allowable load or supportive load was computed for this available increment. The calculated SPM supportive capacity is shown in the following table:

Parameter	**NAAQS ($\mu g/m^3$)**	**Max GLC from Gaussian Plume Model ($\mu g/m^3$)**	**Assimilative load (Kg/day)**	**Max Supportive Incremental Concentration ($\mu g/m^3$)**	**Supportive Load (Kg/day)**
Dust	200	69.5	8772.3	130.41	5719.97
Gas	80	64.87	3508.92	15.134	663.79

Pollution Intensity

Additionally, the amount of pollution load intensity in kg/sq.km of area was computed. Its definition is the amount of pollution in the study zone per unit area. As a result, the pollution intensity will increase as the pollutant load increases. In terms of industrial, vehicular, and home pollutions, pollution load has been estimated. It has been presented in the following table:

Sources of SPM Emissions	**Pollution Load (Kg/day)**	**Pollution Intensity (Kg/km^2)**	**Assimilative Intensity (Kg/km^2)**
Industrial	244630.400	14305.871	20

Conclusion:

From the research conclusions would be as follows:

1. Air pollution load due to industries and increasing industrial development comes out to 244630 kg/day against area of the given study region.
2. Assimilative intensity for the study region comes out to be 20 kg/km^2. This shows marginal assimilative capacity for further pollution. And industrial development if planned in future needs to consider this and stringent rules and regulations need to be implemented to maintain environmental status
3. Above obtained values of various pollution parameters need to be considered for decision making of future industrial development and setting up of new industries.

References

1. Amitabh Kumar Srivastava1 and Arvind K. Nema2 (2011) “Fuzzy Parametric Programming Model for Integrated Solid Waste Management under Uncertainty” Journal of Environmental Engineering ASCE.
2. Bo Xia, Ph.D.1; Albert P. C. Chan2; and John F. Y. Yeung3 (2011)“Developing a Fuzzy Multicriteria Decision-Making Modelfor Selecting Design-Build Operational Variations”Journal of Construction Engineering and Management ASCE.

3. Chintan Y. Pathak, Hiren C. Mandalia, D. Roy and R. B. Jadeja "Comparative Study of Ambient Air Quality Status of Ahmedabad and Gandhinagar City in Gujarat, India" Chemical Science Transactions DOI:10.7598/cst2015.932 2015, 4(1), 89-94.
4. Deshpande A.W., Raje D.V. and Khanna P. "Afuzzy rule-based system for river water quality".
5. Edyta Plebankiewicz and Daniel Kubek "Multicriteria Selection of the Building Material Supplier Using AHP and Fuzzy J. Constr. Eng. Manage., 2016, 142(1): 04015057 ASCE.
6. Guerriere and Detsky, A.S. (1991). "Neural networks: What are they". *Ann Intern Med*, (115) 906-907.
7. H. M. Alhumaidi1 "Construction Contractors Ranking Method Using Multiple Decision-Makers and Multi-attribute Fuzzy Weighted Average" J. Constr. Eng. Management ASCE.
8. Hinton, G.E. (1992). "How neural networks learn from experience". *SciAm* , (267),145-151.
9. Hipel K. W., Radford K.J. and Fang L. (1993). "Multiple participant multiple criteria decision-making."*IEEE Trans. Syst. Man Cybern.*, 23, 1184-1189.
10. Jhumoor Biswas, Era Upadhyay, Mugdha Nayak, Anil Kumar Yadav (2011)"An Analysis of Ambient Air Quality Conditions over Delhi, India from 2004 to 2009" Atmospheric and Climate Sciences, 2011, 1, 214-224 doi:10.4236/acs.2011.14024 Published Online.
11. Md. Asif Ekbal[1] and Hrishabh Gupta (2015) "Assessment of Ambient Air Quality Index of Coal City Dhanbad for Public Health Information" Journal of Energy Research and Environmental Technology (JERET) Print ISSN: 2394-1561; Online ISSN: 2394-157X; Volume 2, Number 1.
12. Murat Gunduz, Ph.D., A.M.ASCE1; Yasemin Nielsen, Ph.D.2; and Mustafa Ozdemir3 "Fuzzy Assessment Model to Estimate the Probability of Delay in Turkish Construction Projects" J. Manage. Eng., 2015, 31(4): 04014055 ASCE.
13. N Sharma, K K Choudhary, C V Chalapati Rao (2005) "Air Pollution Dispersion Studies through Environmental Wind Tunnel (EWT) Investigations: A Review" Journal of Scientific and Industrial Research, Vol 6.
14. Rumelharr, D.E., Hinton, G.E. and Williams, R.J. (1986). "Learning representations by back-propagating errors". *Nature* (London), (323), 533-536.
15. Sadhana Chaurasia, Pragya Dwivedi, Ravindra Singh and Anand Dev Gupta "Assessment of ambient air quality status and air quality index of Bhopal city (Madhya Pradesh), India" INT J CURR SCI 2013, 9: E 96-101 Research Article ISSN 2250-1770.
16. Saurabh Kumar Yadav, Vinit Kumar, M M Singh "Assessment of Ambient Air Quality Status in Urban Residential Areas of Jhansi City And Rural Residential Areas Of Adjoining Villages of Jhansi City" International Journal of Advanced Engineering Technology E-ISSN 0976-3945.
17. Vijai Verma And Y. K. Sharma "Status of ambient air quality in residential and commercial areas of Lucknow" [Vol.8(1), June 2010] Pantnagar Journal of Research.