Critically Polluted Area Analysis using Comprehensive Environmental Pollution Index

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Abstract *Environmental pollution has been a challenging issue for the past few decades which have been aggravated by industrialization across the country. Industrial developments could not be ignored as they are backbone of economics of a country. To address problem, the Study is done which is typically based on usage of data measuring ambient air, Groundwater and Surface water quality from various point locations in study area. This study focused on the Ghaziabad District of Uttar Pradesh, India. Study area is highly industrialized. Environmental pollution index (EPI) is calculated by selecting three most critical pollutants for Air, Surface water and Groundwater. Thereafter, Comprehensive Environmental Pollution Index (CEPI) is calculated by selecting three most critical parameters for air, water and Groundwater in 16, 06, and 16 monitoring locations respectively. In industrialized urban areas, this approach may present critical issues due to the spatial complexities of air pollutants which are emitted by different sources. The objectives of study is to show variability of pollutants in Air, Surface water and Groundwater and to interpret the results in relation to the applicability of data in assessing population exposure. Relative and absolute spatial concentration variations were investigated by means of Inverse distance weighting (IDW) tool in GIS, which is a kind of approach for multivariate interpolation taking a known scattered set of points. Results suggest evaluating the population exposure to pollutants in study area by taking into account the possible zones of influence of different emission sources.*

Key Words: Geographical Information System, IDW, deterministic approach, CPA, Ghaziabad

1. INTRODUCTION

Environmental pollution has been a challenging issue for the past few decades and it endangers the health of livings. The problem of pollution and its corresponding harmful ecological impacts have been increased by industrialization across the country and affecting the life of billions of people, other living creatures and damaging the natural resources locating nearby. Industrial developments could not be ignored as they are backbone of economics of a country. The micro, small and medium enterprises sector has emerged as a highly vibrant and dynamic sector of the Indian economy over the last five decades and most of them are concentrated in Industrial areas. Industrial areas specifically concentrated with large, medium and small scale industries with different category are in alarming condition and there is a need to restore the quality of the environment. There is an urgent need to identify critically polluted areas and their problematic dimensions. The Government shall take measure to the purpose of protecting and improvement in quality of the environment. The quality of the environment is studied by monitoring the environmental components such as water, air and land and health of human and other living creatures. The monitoring data does not help the policy makers and other public to understand the quality of environment system. A weighted measurement of environmental performance or sustainability, in form of comprehensive environmental pollution index (CEPI) is very useful. CEPI gives the idea about how much an industrial area is environmentally sound by using information on status of environment provided with quantity data.

Environmental quality assessment, in the form of index is a complex process which has limited study. As the present method of assessment of pollution studies does not give clear picture on the quality of environment to the public and policy makers, there is a need to form a common code/number/description. In view of this, an index with description was needed and an innovative concept of CEPI has been developed by Central Pollution Control Board, Government of India. The index value will be derived based on the available sources of pollution, presence of the pollution, level of the pollution and number of exceedance of the pollution, impact on health of human, ecosystem and the preventive action taken in controlling the environmental pollution are playing important role in establishment of the quality index value. To evaluate the CEPI scores of polluted industrial areas, a project on 'Monitoring, sampling and analysis for ambient air quality, surface water quality and ground water quality in 100 polluted industrial areas' has been carried out in 2018. The outcome of the project studies is presented in this paper.

1.1 Comprehensive Environmental Pollution Index

Comprehensive Environmental Pollution Index (CEPI) is a rational number to characterize the environmental quality at a given location following the algorithm of source, pathway and receptor. The concept of CEPI was developed by IIT Delhi, CPCB and many other organization like NEERI, TERI and DTU. CEPI was calculated on basis of various factors and three rounds of monitoring have been undertaken by CPCB in 2009, 2011, 2013 and 2018 on basis of which, CEPI assessment has been done periodically. CEPI is calculated by using the following formula

$$CEPI = i_{max} + [(100 - i_{max}) \times (i_2/100) \times (i_3/100)]$$

Where, i_{max} is maximum index (which may be Air EPI or Surface Water EPI or Ground Water EPI);
and i_2, and i_3 are indices for other media
EPI of surface water, air and groundwater are evaluated on a scale of 1-100 using the formula
EPI = A+B+C+D
Where A-source, B- pathway, C-receptor and D- additional high risk elements.

1.2 Elements of CEPI

Three criteria pollutants are selected for air, water and land based on the pollutants relevant with the Area depending on the nature of industrial activity (preferable option /method) or depending on the concentration and exceedance. For selected criteria pollutants, scoring is done for A, B, C and D element for EPI calculation of air, water and land. Scoring methodology is described as below:

- A - Source: factor 'A' comprise of A_1 and A_2 as sub components. A_1 is based on the data on presence of toxins with maximum value 5. A_1 score for selected one primary and two secondary pollutants is given as per the group in which the pollutant lies.

Table-1: Source factor score for criteria pollutants

Group of toxicity	Property for pollutants in respective group	Contribution Value for Primary pollutant	Contribution Value for each of the Secondary pollutant
Group A	Pollutants not classified as acute or systematic	1	0.25
Group B	Pollutants/organics that are probable carcinogens or with systematic toxicity.	2	0.50
Group C	Known carcinogens or chemicals with significant systemic or organ system toxicity	3	1.00

Source: cpcb.nic.in

Component A_2 is based on the scale of industrial activities as no. of small scale, medium scale and large scale industrial units in given industrial cluster with maximum achievable score of 4. Large = 4 (if there are > 10 R17 per 10 sq km area or fraction OR > 2 R17 + 10 R54 per 10 sq km area or fraction OR > 100 R54 per 10 sq km area or fraction. Moderate = 2.5 (if there are 2 to 10 R17 per 10 sq km area or fraction OR 10-100 R54 per 10 sq km area or fraction. Limited = 1 (else there is any industry within 10 sq km area or fraction). This is how the 'A' score is calculated by multiplying A_1 and A_2.

- B - Pathway Factor: pathway factor is based on the level of exposure which is calculated by the Surrogate Number Level Factor (SNLF). SNLF is calculated using % violation of ambient pollutant concentration and ratio of no. Of samples exceeding prescribed standard value to the total no. of samples collected.

Table-2: Category classification on SNLF basis

Range of SNLF	Category	Contribution Value for Primary pollutants	Contribution Value for each of the secondary pollutants
(For EF > 0.75)	Low	0	2.5
7.5 < 0.50	Moderate	15	5.0
0.5 to < 1.0	High	22.5	7.5
1.0 and above	Critical	30	10.0

Source: cpcb.nic.in

- C - Receptor Factor: Percent increase is evaluated based on the total no. of cases recorded during two consecutive years. For Air Environment, total no. of case related to Asthma, Bronchitis, Cancer, Acute respiratory infections etc. are to be considered. For surface water / ground water Environment, cases related to Gastroenteritis, Diarrhea, renal (kidney) malfunction, cancer etc. are to be considered. For the above evaluation, the previous 5 years' records of 3-5 major hospitals of the area shall be considered.

Table-3: Health impact score

C (Impact on Human Health) = 10	
Increase in cases	Marks
<5%	0
5-10%	5
>10%	10

Source: cpcb.nic.in

- D – Additional high risk element factor: scoring of 'D' element is based on the adequacy status industries and common facilities like Common effluent treatment plant (CETP), Final effluent treatment plant (FETP) and Common hazardous waste.

Table-4: Score for Additional High Risk Element: Factor D

Large Scale Industries	Small/ Medium Scale Industries	Common Facilities for Pollution Control	Score
Adequate	Adequate	Adequate	0
Adequate	Inadequate	Adequate	5
Adequate	Adequate	Inadequate	10
Adequate	Inadequate	Inadequate	15
Inadequate	Inadequate	Inadequate	20

Source: cpcb.nic.in

2. STUDY AREA AND METHODOLOGY

Study area includes industrial area of Mohan nagar/Mohan Meakin Industrial area, Rajender nagar Industrial area, Sahibabad Industrial area, South side of Grand trunk road industrial area, Sahibabad, Sahibabad industrial area Site-4, Pandav nagar Industrial area, Kavi nagar industrial area, Bulandshahar road industrial area, Amrit nagar, Arya nagar industrial area, Meerut road industrial area, Loni industrial area, Loni road industrial area, Roop nagar industrial area,

Hapur road industrial area, Dasna, Philkua, South side of GT road, Kavi nagar, Tronica city, Anand nagar, Jindal nagar, Prakash nagar, Rural Industrial estate in Ghaziabad, Uttar Pradesh state of India.

Fig-1: Study Area

2.1 Methodology Involved

The aggregated CEPI Score can be calculated as.

$CEPI = i_m + \{(100 - i_m)*(i_2/100)*(i_3/100)\}$

Where, i_m: maximum sub index; and

i_2, and i_3 are sub-indices for other media.

To study the spatial variation of pollutant over the area, GIS is used.

Steps involved in creating the GIS images of spatial variation of pollutants over the study area are:

1. Creating the Base map of Study area (here, Ghaziabad) by Geo-referencing in GIS.
2. Adding base map in blank sheet.
3. Adding X-Y coordinates as respective latitudes and longitudes of the study area over its base map.
4. Exporting data of Ambient air pollutants, Surface water pollutants and groundwater pollutants one at a time over the base map.
5. Using Inverse Distance weighing tool to calculate the assigned value to unknown points with a weighted average of the values available at the known points.
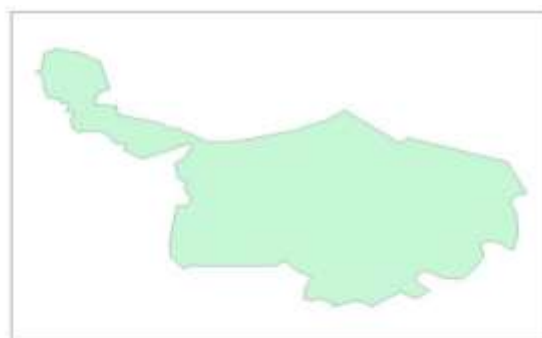
Fig-2: Basemap of Ghaziabad

3. RESULTS AND DISCUSSION

3.1 Air Quality Analysis

Available data of year 2018 of air pollutants from sixteen monitoring locations is assessed and analyzed over whole study area. Discrete data is used to create continuous variation of pollutants over basemap. IDW interpolation technique is used to map the spatial extent of pollutants to show the desired variation in simple and intuitive manner.
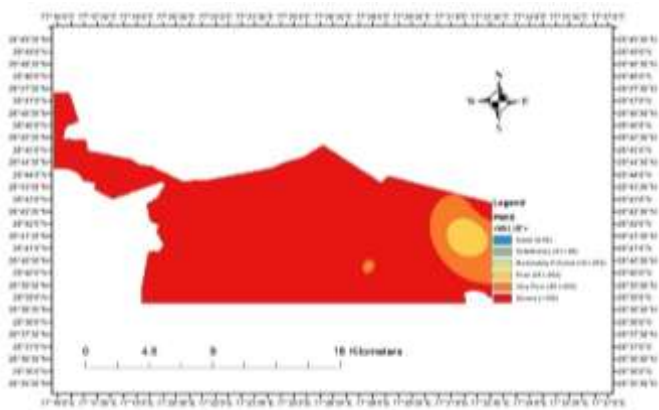
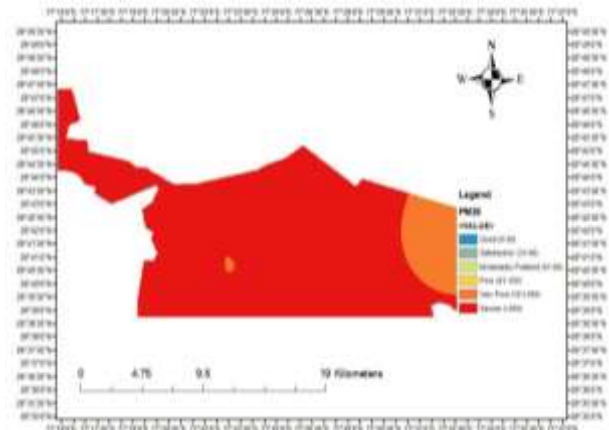**Chart-1**: Spatial variation of PM_{10}
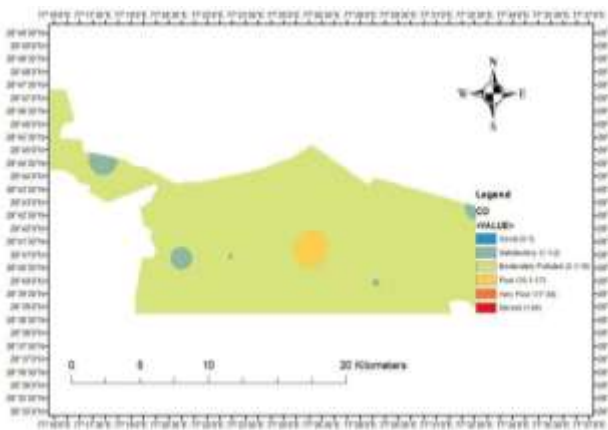

Chart-2: Spatial variation of $PM_{2.5}$

Chart-3: Spatial variation of CO
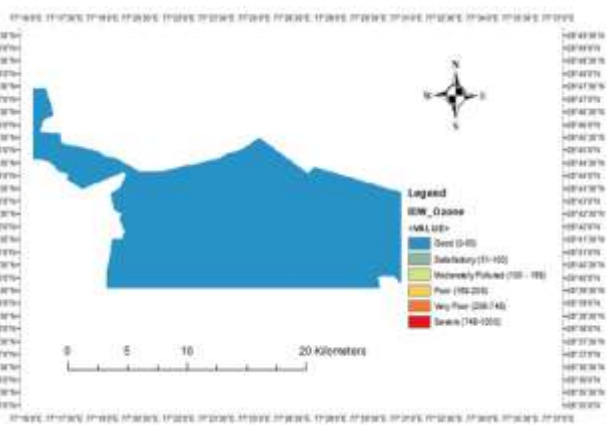
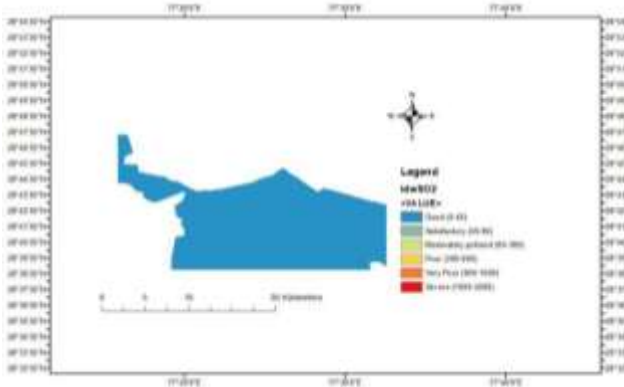**Chart-4**: Spatial variation of O_3
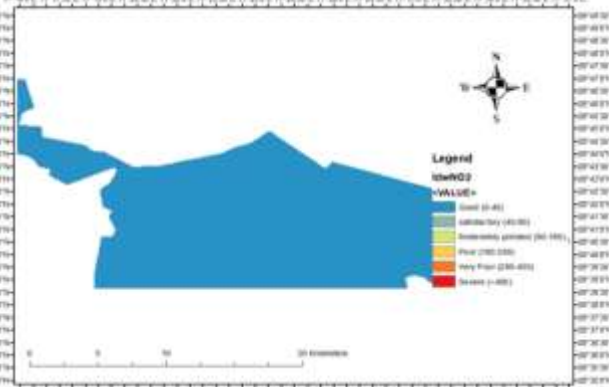

Chart-5: Spatial variation of SO_2

Chart-6: Spatial variation of NO_2

3.2 Surface Water Quality Analysis

Available data of year 2018 of surface water pollutants from six monitoring locations is assessed and analyzed over whole study area.
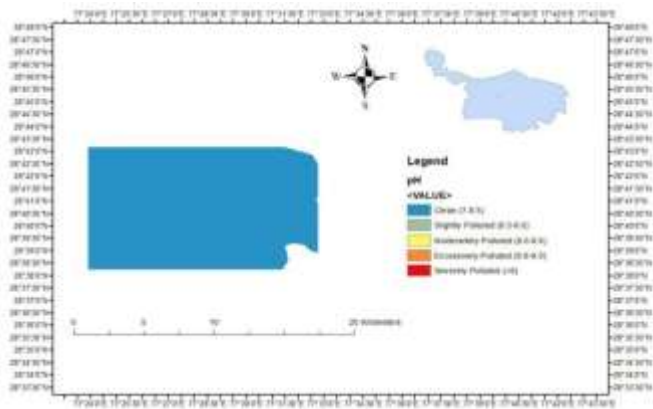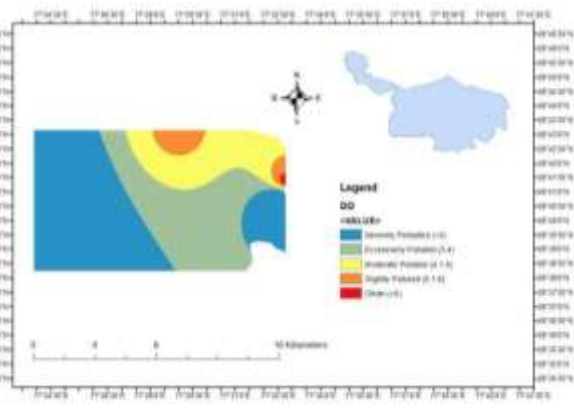
Chart-7: Spatial variation of pH
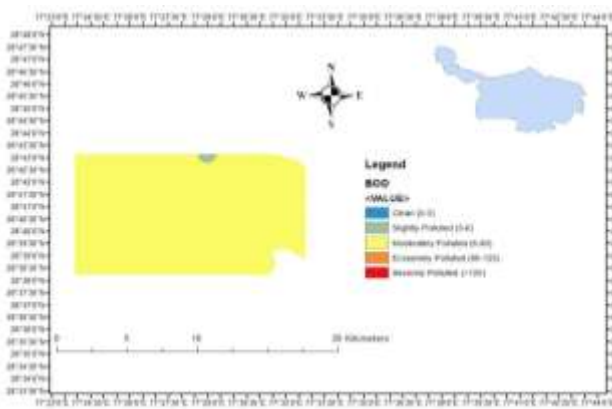

Chart-8: Spatial variation of DO

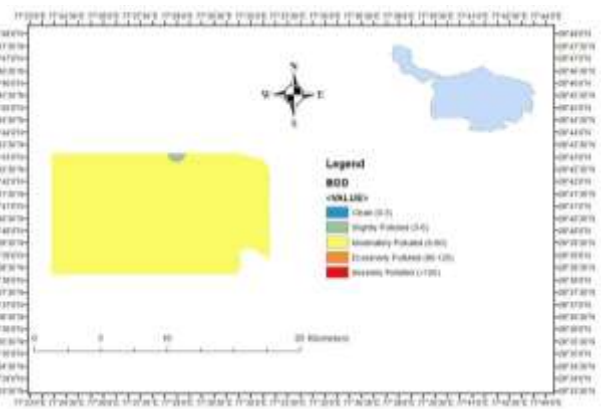**Chart-9**: Spatial variation of BOD

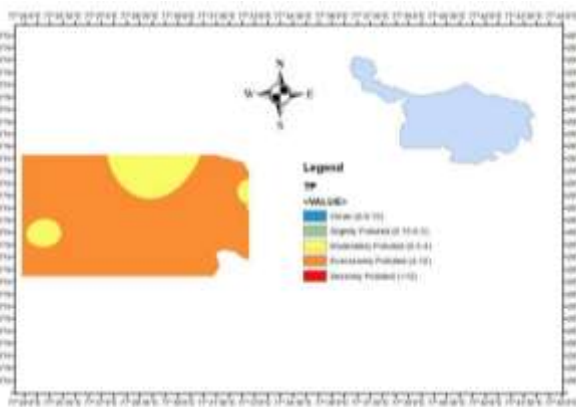**Chart-10**: Spatial variation of ₛₒdium Absorption ratio

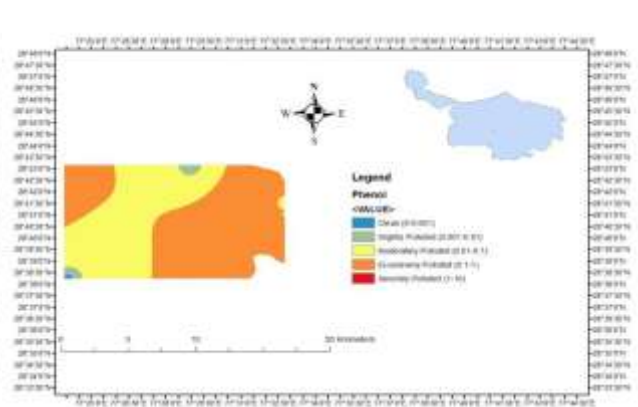**Chart-11**: Spatial variation of Total Phosphate

Chart-12: Spatial variation of ₚhenolic Compounds

3.3 Ground Water Quality Analysis

Available data of year 2018 of surface water pollutants from sixteen monitoring locations is assessed and analyzed over whole study area
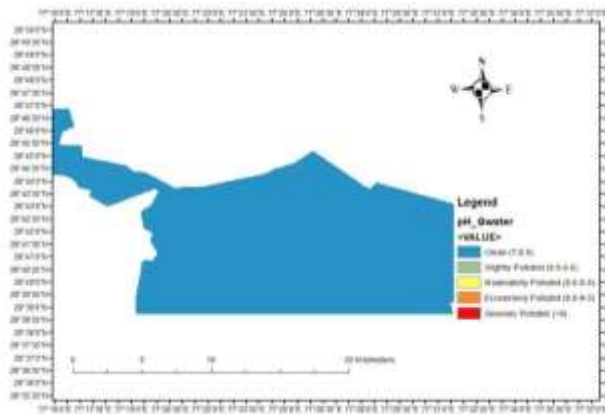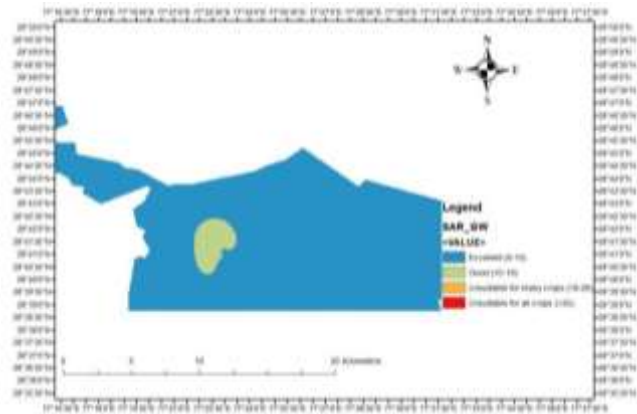
Chart-13: Spatial variation of pH

Chart-14: Spatial variation of $_{Sodium}$ Absorption ratio
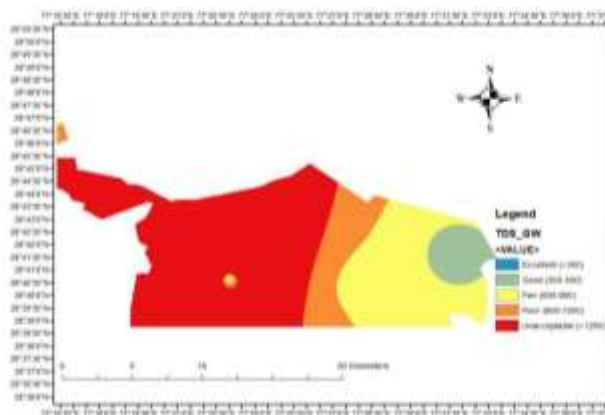

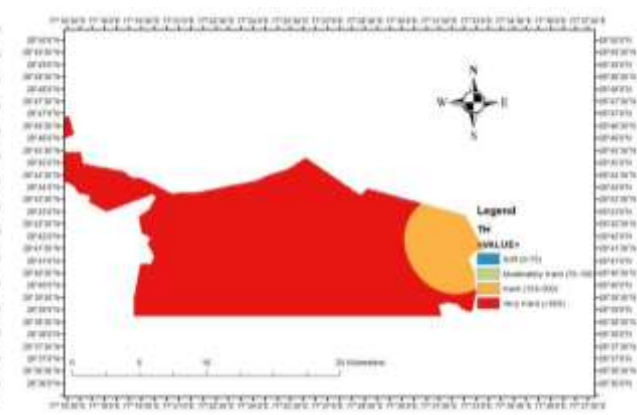**Chart-15**: Spatial variation of Total Dissolved Solids

Chart-16: Spatial variation of Total Hardness

3.4 Air EPI Calculation

For Ambient air quality analysis in Ghazibad area, PM_{10} is exceeding the standard of PM_{10} ($80\mu g/m3$ for 24-Hr average) prescribed by CPCB in all 36 samples out of 36 ambient air samples analyzed at 16 ambient air quality monitoring locations and considered as primary critical pollutant.

In similar fashion $PM_{2.5}$ is exceeding the standard of $PM_{2.5}$ ($80\mu g/m^3$ for 24-Hr average) prescribed by CPCB in all 36 samples out of 36 ambient air samples and Carbon Monoxide (CO) is exceeding in 20 samples out of 36 ambient air samples collected by the standard fixed by CPCB for CO ($2mg/m^3$ for 8-Hr, average). Since PM_{10} categorized as group B pollutant i.e., Probable carcinogen and thus scored 2 points in industrial activity calculation and $PM_{2.5}$ and CO being Secondary critical pollutant and categorized as Group B pollutant thus scored 0.5-0.5. As per the data collected, there are more than ten R17 category industries in Ghaziabad per 10 KM^2 area under the polluted industrial area considered. Thus Ghaziabad PIA categorized as Large on scale of industrial activities

Surrogate Number Level factor (SNLF) is a function of Exceedance factor and ratio of no. Of samples exceeding the standard to total no. Of samples analyzed. It is calculated as described in methodology giving B score as 45.5 with PM_{10} scored 30 as primary critical pollutants and $PM_{2.5}$ scored 10 as secondary critical pollutant SNLF is > 1 and CO being secondary critical pollutant with SNLF 0.56 scores 5.5 giving collective value of B as 45.5.

 Score C corresponds to the health data received from at least major three to five hospitals situated in PIA. For Air EPI calculation, annual percent increment in the patients suffering from air Borne diseases like Asthma and Bronchitis received by hospital is calculated for past five years. Here for Air EPI calculation in year 2018, annual percent increment in no. of patients are less than 5% hence the Receptor score is given as 0.

For D score, the adequacy of large/medium/small scale industries and Compliance of CETP/STP/ETP/CHWTSDF and MSW management facilities is observed. For Ghaziabad, in the demarcated PIA, industries as well as waste management facilities are complying thus resulting in D score as zero.

3.5 Water EPI Calculation

Phenolic compounds, Total Phosphorus and BOD are taken as primary, secondary and secondary critical parameters respectively according to the surface water samples collected and tested further. BOD is exceeding the standard (5 mg/l) given by CPCB in 14 samples out of 27 samples collected from monitoring locations. Total Phosphorus is exceeding at all 27 locations and being a probable carcinogen it lies in group B scoring 0.5 points. Phenolic compounds exceeding the standard of Phenolic Compounds (0.01 mg/l) for surface water prescribed by BIS. Phenolic compound being the Carcinogenic compound lies in group C and scores 3 giving total score of A1 as 4 and A as 16.

For B score calculation, SNLF calculated is highest for Total Phosphorus and thus TP is taken as primary critical pollutant giving B1 score 30 (as SNLF is above 1) and marked as critical. Two runner ups with highest SNLF next to TP is considered as secondary critical pollutant and scored 10 points for having SNLF greater than 1 for each of them. B2 and B3 score for BOD and Phenolic compound is calculated in similar manner giving total B score as summation of B1, B2, and B3 as 50. Thus, total water EPI came out as 66 categorizing water in PIA as critical.

3.6 Land EPI Calculation

Out of total 23 parameters tested for groundwater sample collected from 17 monitoring locations in demarcated PIA, three most critical parameters are selected on basis of exceedance. For A score calculation mercury is found exceeding the standard prescribed by BIS for Mercury (0.001 mg/l) in groundwater and since C lies in group C category and is a known carcinogen thus it is considered ass primary critical pollutant and scored 3 points. For other two parameters Total Hardness and Total Dissolved Oxygen as group A parameter scored 0.25 points each. For B score calculation SNLF calculated is highest for Total Hardness among three critical pollutants selected and considered for Primary critical pollutant and scored accordingly 11.25 points with Moderate label giving total B score of 18.25. Other two secondary critical pollutants scored 3.5 score with moderate label and since health related and adequacy score were zero thus total Land EPI came out as 32.25. Land is categorized as Normal.

$$CEPI = i_{max} + \{(100 - i_{max}) \times (i_2/100) \times (i_3/100)\}$$

$$= 66 + 34 \times (57.5/100) \times (32.25/100)$$

$$= 72.3$$

4. CONCLUSIONS

In the study area, Ambient air quality of samples are analyzed for all the 12 notified parameters however the predominant pollutants identified were PM_{10}, $PM_{2.5}$ and CO as critical pollutants. At some locations benzene and heavy metals were also identified. It is interpreted that majorly vehicular movement and vehicular emission due to burning of fuel is responsible for $PM_{2.5}$ and PM_{10} and Recessively, emissions of SO_2, NO_2, ammonia and VOCs is a reason in formation of the inhalable particulate matter ($PM_{2.5}$) by photochemical reactions. Ambient air component has been observed severe in Ghaziabad Industrial area. Similarly, in terms of water quality, the BOD, Phenolic Compounds, TP, Total Hardness, TDS and Hg are predominant parameters and most of the other parameters were not significant. The specific pollutants such as PAH and Hg are reported in some locations. Surface water is observed critical in Ghaziabad industrial areas with BOD, TP and Phenolic compounds as critical parameters. Whereas, ground water is in normal condition.

The CEPI analysis helps to categorize industrial areas/clusters into critically polluted area, severely polluted are and other polluted area with respect to one or more environmental component. The areas having aggregated CEPI scores of 70 and above are considered as critically polluted industrial clusters/ areas, whereas the areas having CEPI between 60-70 are considered as severely polluted areas and they are kept under surveillance and pollution control measures, whereas, for the critically polluted industrial clusters/ areas further detailed investigations in terms of the extent of damage and a formulation of appropriate remedial action plan. It is recommended that as the step II a comprehensive analysis of spatial and temporal data shall be done for the identified critical polluted industrial clusters/ areas so as to define the spatial boundaries and extent of damage to the eco-geological features.

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