Air quality depreciation index in a coal mining area- a case study from eastern India

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Abstract: The comparison with National Ambient Air Quality Standards does not always depict a true picture of the Air Quality Status of a study area. As an alternative an index that measures depreciation in Air Quality on more realistic terms has been proposed and applied to the ambient air monitoring data collected from Talcher Coalfields in India. Results have been discussed in detail to illustrate the application of the proposed index and utility in bringing out more realistic air quality assessment [Journal of American Science 2010;6(5):107-114]. (ISSN: 1545-1003).

Key words: National Ambient Air Quality Standards, value function curves, air quality depreciation index

1.0 Introduction

Coal mining and coal based thermal generation activities result in serious pollution problems due to release of particulates and noxious gases in the atmosphere. Over the past few years, with the introduction of mechanized mining techniques and heavy earth moving equipments, this problem has been further aggravated (Singh and Sharma, 1991; Sharma and Singh, 1992). Air quality assessment in Korba Coalfield also revealed an unsatisfactory air quality there. The concentration of respirable particulate matter (RPM) was found to be at an alarming level there (Singh and Puri, 2004). In opencast mines all the major mining activities directly or indirectly contribute to air pollution. Sharma & Singh (1990) found that unloading and loading, transportation of coal, poor condition of roads and huge quantities of open air coal burning were responsible for air pollution in coal mines.

Mining operations share a number of common stages or activities each of which has potentially adverse impacts on the natural environment. The health and safety status of the occupational and the communities in the environs of the mine may also be affected as a result of mining. Like other industries, social and cultural conditions of the concerned environment may accordingly be modified. In absence of appropriate control measures mining operations may lead to environmental disturbances. The impact of a mining operation commences with exploration activities, extends through extraction and processing of minerals and may continue even after closure of the operation. One of the important environmental impact of mining is the degradation in the air quality.

The monitoring and evaluation of ambient air quality is first important step in controlling air pollution. Current approaches to the evaluation of air quality in India are based entirely on the comparison of measured concentration of pollutants with National Ambient Air Quality Standards (NAAQS). A comparison of data with NAAQS serves the purpose to some extent, but this cannot map the periodical degradation in the air quality, particularly if the measured values remain below NAAQS. A number of air quality indices have been formulated (Babcock, 1970 and Ricci, 1979). Most of the indices take NAAQS standards as the base for devising the scale. There are other systems, which are independent of the NAAQS and based on the measurement of air quality (with due weightage to the potential of pollutants to affect biophysical, health and aesthetic attributes) on an absolutely environmental quality scale and not in relation to NAAQS.

Although the use of this approach to some extent helps to maintain a 'desired' environmental quality, it does a little to 'map' periodic degradation in air quality, particularly if the measured values remain below NAAQS. The reason behind this drawback arises from the fact that by providing an upper threshold concentration value in the form of a standard, air quality tends to get categorized either as 'good' or 'bad' depending on whether the standards have been exceeded on not. In reality, however, there are instances where concentration of pollutants become sufficiently high to pose environmental and health problems, but owing to the fact that may not falsely interpreted to represent 'acceptable' air quality.

Viewed in this backdrop, the present paper attempts to propose an air quality depreciation index that measures deterioration in air quality (with due weightage to the potential capacity of pollutants to affect bio-physical, health and aesthetic attributes) on an 'absolute' environmental quality scale independent of NAAQS.

1.1 Air Quality Depreciation Index

The air quality depreciation index, as proposed here, attempts to measure deterioration in air quality on an arbitrary scale that ranges between 0 and –10. An index value of '0'represents most desirable air quality having no depreciation from the best possible air quality with respect to the pollutants under consideration while an index value of –10 represents maximum depreciation or worst air quality. Index values differing from 0 towards –10 represent successive depreciation in air quality from the most desirable. The air quality depreciation index is defined as follows:

$$AQ_{dep} = \sum_{i=1}^{n}(AQ_i \times CW_i) - \sum_{i=1}^{n} CW_i \quad ....(1)$$

where,

AQ_i = Air quality index value for i^{th} parameter

CW_i = Composite weight for i^{th} parameter

n = Total no. of pollutants considered

The values of the AQ_i are obtained from the value function curves. In the value function curves the value of 0 signifies worst air quality and value of 1 represents the best air quality for corresponding pollutant concentration. Typical value function curves for SPM, SO_2, NO_x and (TSP x SO_2) are given in Figures 1, 2, 3 and 4, respectively.

Value of CW_i in equation (1) is computed using the following expression:

$$CWi = \frac{TW_i}{\sum_{i=1}^{n} TW_i} \times 10 \quad ....(2)$$

where,

TW_i = Total weight of i^{th} parameter

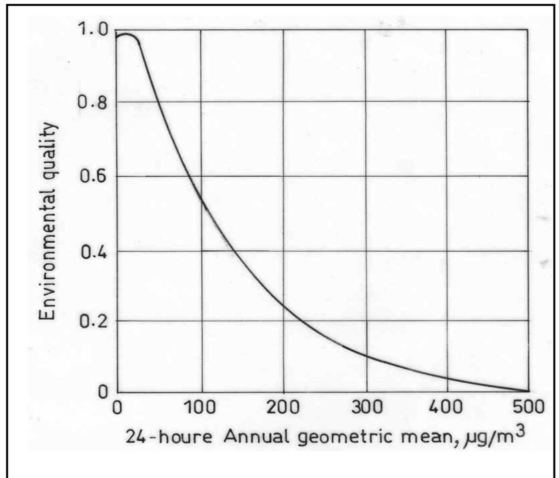
$$= AW_i + BPIW_i + HW_i$$

where,

AWi = Aesthetic weight for i^{th} parameter

BPIWi = Bio- Physical Impact Weight for i^{th} parameter

be high enough to cross the threshold value, they are



HWi = Health Weight for i^{th} parameter

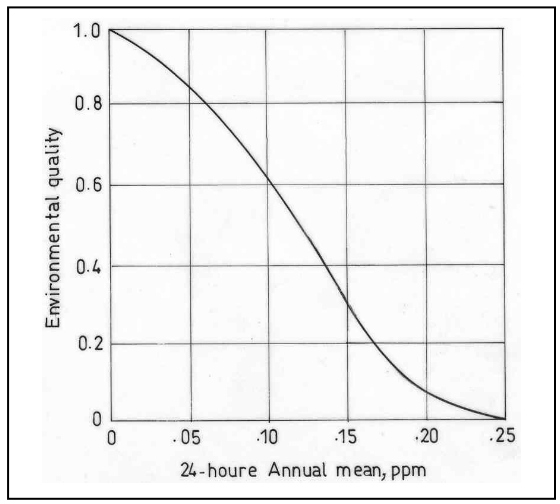


Figure 1. Value function curve for suspended particulate matter (Jain et al. 1977)

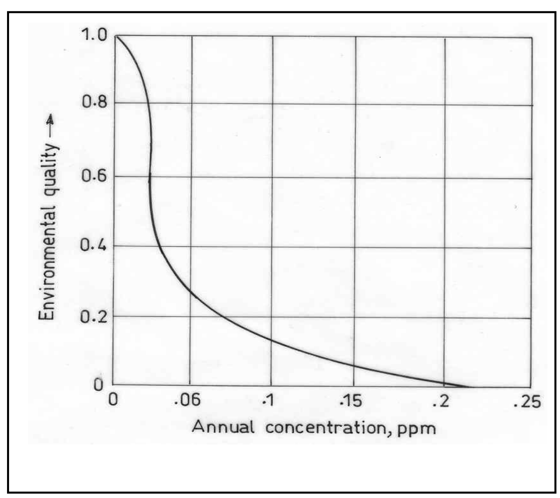
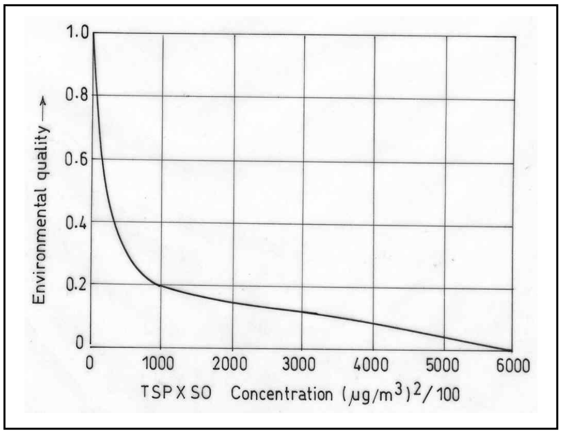


Figure 2. Value function curve for sulphur dioxide (Jain et al., 1977)
Figure 3. Value function curve for nitrogen oxides



(Jain et al., 1977)

Figure 4. Value function curve for TSP × SO_2 (Luhar & Khanna, 1988)

In computing TW_i, an importance weight between 1 to 5 is subjectively assigned to AWi, BPIWi and HWi (i.e. for the i^{th} pollutant) by a team of assessors or experts. Least important assignment is 1 and most important marking is 5. The weights are then aggregated in accordance with equations (2) and (3).

2.0 Materials and methods

The air quality depreciation index was applied to the set of data obtained from monitoring ambient air quality of some coal mining areas of Talcher coal field (Fig. 5) of MCL (Orissa). The Talcher Coalfields constitutes mostly the south-eastern part of the Lower Gondwana Mahanadi Master Basin and occupies an area of over 1813 sq km. The coalfield is bounded by latitudes 20°50' N and 21°15' N and longitudes 84°09' E and 85°33' E. This basin mainly occupies the Brahmani River Valley. It covers parts of Dhenkanal and Angu1 districts along with a small portion of the adjoining Sambalpur District of Orissa. The main sources of air pollutants located in this region are Talcher Thermal Power Station (TTPS) and the extensive mining industries of MCL and other allied industries.

Systematic air quality monitoring was carried out at twenty one sampling stations (Fig. 6) in the study area using Respirable Dust Samplers (Envirotech-make Model APM 460) with thermoelectrically cooled impinger attachment for gaseous sampling. 24-hourly ambient air samples were collected for SPM, PM_{10}, SO_2 and NO_X. The impinger samples (containing SO_2, NO_X in specific absorbing solutions) were analyzed spectrophotometrically using Scanning Visible Spectrophotometer (VIS-7200). Improved West-Gaeke method and Jacob & Hocheiser modified methods were used for analysis of SO_2 and NO_X, respectively as per standard methods prescribed by Central Pollution Control Board (CPCB, July 2003), India.

3.0 Results and discussions

Assignment and computation of Composite Weight for different pollutants is given in Table 1. Air Quality monitoring results for Talcher mining Belt is summarised in Table 2. Values for AQ_i and AQ_{dep} calculated as per equation (1) are given in Table 3. For MCL Coalfield the air quality depreciation values are depicted in Table 3.

Comparison with NAAQS cannot forcefully categorize air quality as 'objectionable' or 'unacceptable'. Till standards are exceeded, there is no indication of deterioration in air quality from what can be considered 'truly acceptable air quality'. Results of air quality monitoring in the study areas show that the concentration levels of SPM and PM_{10} exceeds the NAAQS while concentration levels of NOx and SO_2 are found to be below the NAAQS at most of the sampling stations of both the study area. So the overall results do not provide a clear picture about the Ambient Air Quality status of the study areas. If all the pollutants exceeded the NAAQS then the air quality of the station could be referred to as 'objectionable' or 'unacceptable'. But this situation does not prevail in the study areas. Application of the air quality depreciation index to the observed data, however, clearly 'maps' this deterioration in the quality of air around these mining sites. Depreciation in air quality from the desired value of 0 is clearly apparent, as AQ_{dep} values at all the locations of the study area are less than -1.0.

The deterioration in the Air Quality in the coal mining areas of Talcher Coalfields can be undoubtedly visualised in the Table 3. Depreciation in air quality from the most desired value of '0' is clearly apparent, as AQ_{dep} values at all the locations are less than -1.0. After assigning rank to the resulted depreciation values it was found that Ananta OCP (A3) had the highest depreciation value (-4.59) followed by Jagannath OCP (A4), Lingraj OCP(A1) and Bhubaneswari mines (A2) with depreciation values -4.50, -3.21 and -3.20, respectively. Among residential and other areas Dera chowk (A15) had higher depreciation value (-3.10) followed by Jagannathpur village (A13) with depreciation value -2.85.

This pointed out that mining premise was the most polluted area followed by traffic junction. The results also suggest that the Raghunathpur Village has the best air quality followed by TTPS Guest House Colony.

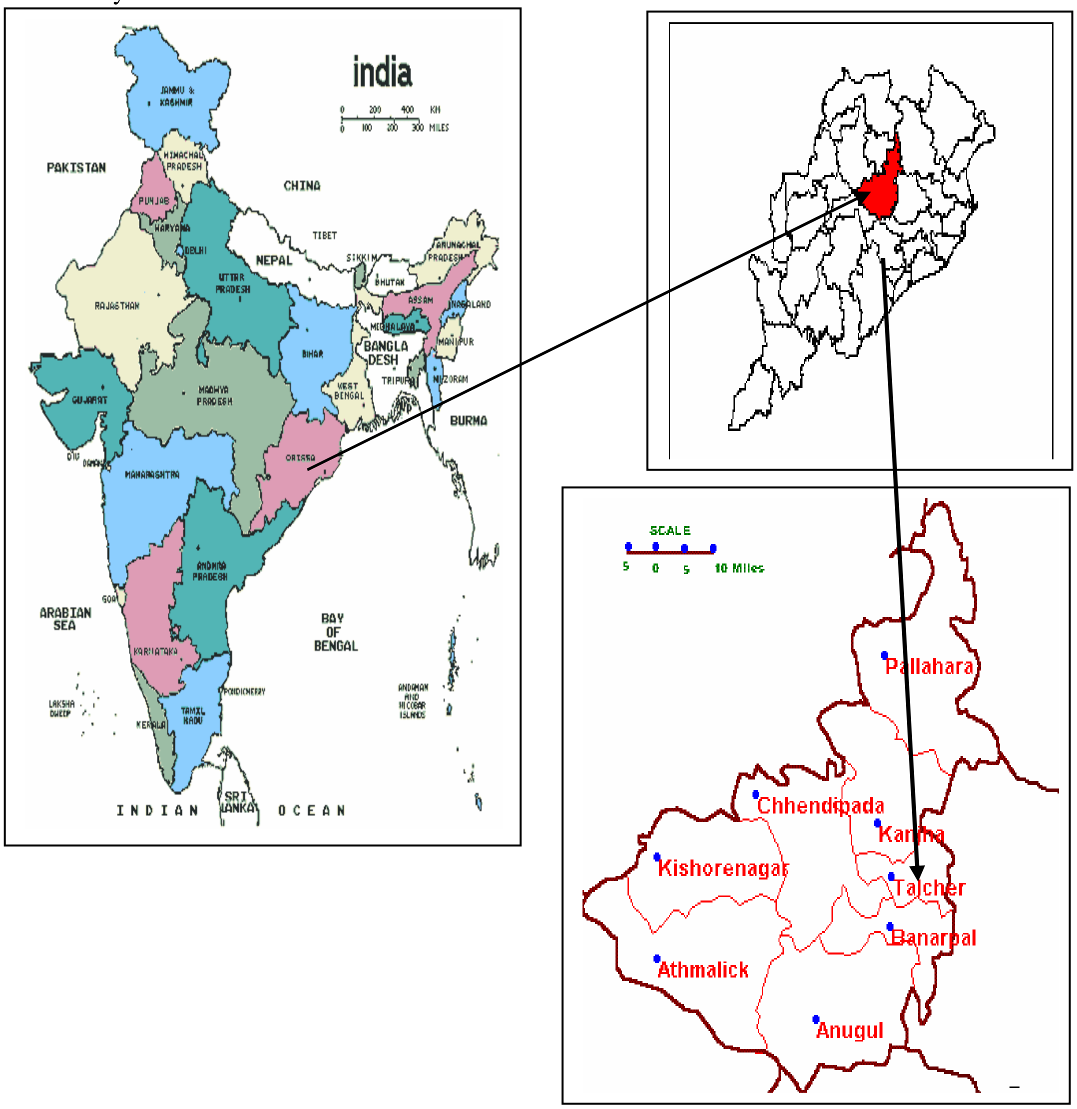
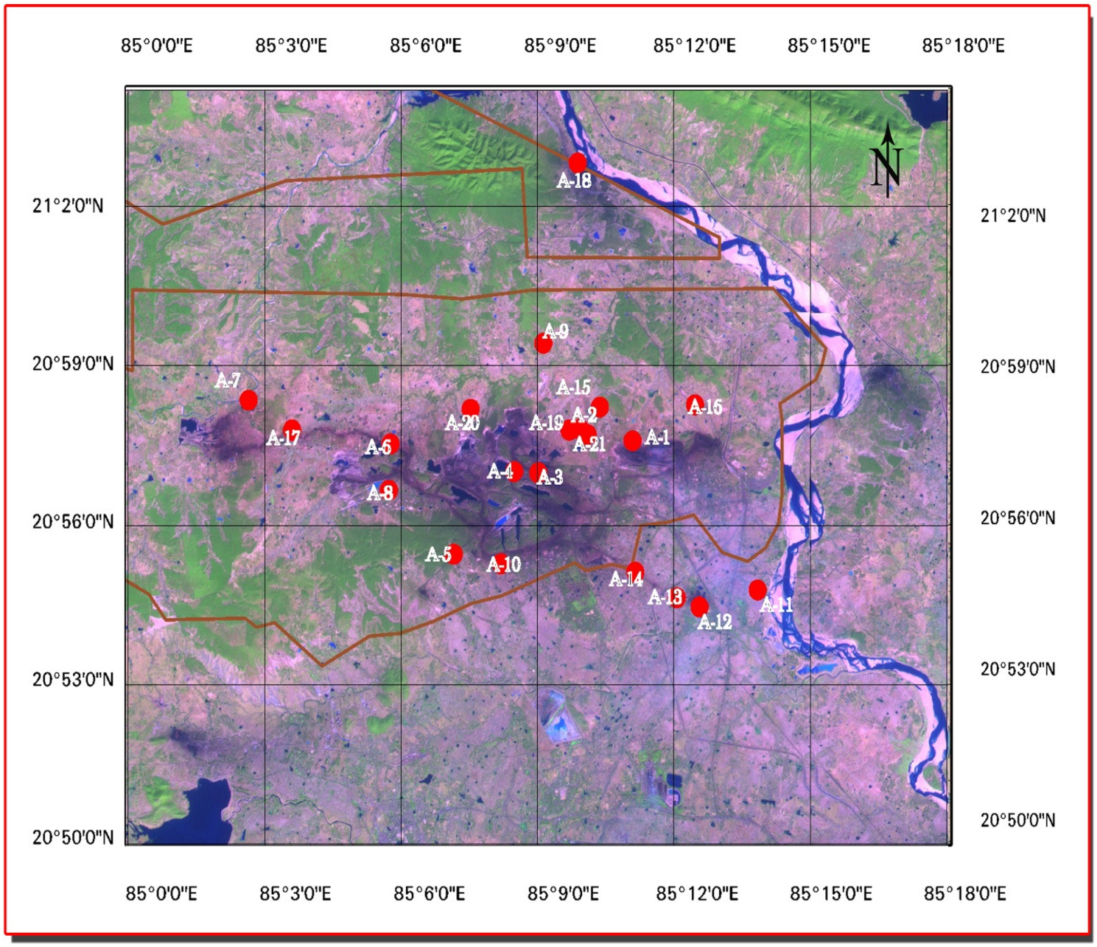


Figure 5. Location map of the study area.

Table 1. Assignments and computation of composite weight for different pollutants

Pollutants	AWi (Range 1-5)	BPIWi (Range 1-5)	HWi (Range 1-5)	TW_i	CW_i
SPM	4	4	3	11	3.1
SO_2	1	4	4	9	2.5
NO_x	2	3	3	8	2.2
SPM X SO_2	1	2	5	8	2.2

$$\sum_{i=1}^{n} TW_i = 36$$



A1-Lingraj OCP[a]	A2- Bhubaneswari Mines	A3-Ananta OCP	A4-Jagannath OCP
A5-Bharatpur Colony	A6-kalinga Township	A7-Gopal Prasad village	A8-Donnara village
A9-Raghunathpur village	A10-Barasinghra village	A11-Talcher guest house	A12-TTPS Residential area
A13-Jagannathpur village	A14-Sharma chowk	A15-Dera chowk	A16-Talbera village
A17-Kalamchui village	A18-Ekgharia village	A19-Ananta Guest House	A20-Rakash village
A21-Mukundnali village	[a]Open cast project		

Air sampling stations

Coalfield boundary

Scale

Kilometers

Figure 6. Air quality sampling stations

Table 2. Ambient air quality monitoring results of MCL coal mines of Talcher coalfield

Locations	Code	SPM[1]	TSP[2]	SO_2	NOx	SPM[3]	TSP*SO_2/ 100
Lingraj OCP	A1	278.92	422.87	27.04	34.75	274.11	1.16
Bhubaneswari Mines	A2	233.58	324.87	28.29	35.71	227.93	0.93
Ananta OCP	A3	500.71	773.79	29.33	31.83	490.73	2.31
Jagannath OCP	A4	440.79	639.29	31.0	36.0	434.29	2.03
Bharatpur Colony	A5	190.83	280.71	25.5	30.92	188.39	0.73
Kalinga village	A6	196.67	286.29	25.96	28.25	193.80	0.76
Gopalprasad village	A7	121.37	181	23.58	27.12	119.85	0.43
Utkal village	A8	118.62	176.21	21.21	23.46	117.21	0.38
Donnara	A9	177.25	268.13	19.91	26.62	166.86	0.55
Raghunathpur village	A10	109.42	165.08	24.33	27.79	105.20	0.41
Barasingra village	A11	193.92	286	22.45	31.75	192.97	0.65
TTPS Guest House	A12	117.58	178.96	25.37	27.79	116.08	0.45
TTPS residential	A13	129.37	195.46	26.95	29.37	125.27	0.53
Jagannathpur village	A14	224.75	330.12	25.83	31.71	212.01	0.86
Sharma Chawk	A15	152.46	237.29	28.08	31.17	144.56	0.67
Dera Chawk	A16	287.83	437.58	37.58	38.08	280.92	1.68
Talbera village	A17	126.75	183.67	20.66	24.83	126.00	0.38
Kalamchui village	A18	141.12	206.37	23.63	25.92	136.35	0.48
Ekghari village	A19	149.5	212.83	23.54	26.42	144.9	0.50
Ananta Guest House	A20	148.46	213.12	26.75	28.37	140.74	0.57
Rakash village	A21	153.29	221.25	25.33	25.17	139.95	0.60
Mukundnali village	A22	120.21	170.62	24.66	29.25	117.16	0.42
[4]NAAQS		500	800	120	120		

1 - Arithmetic Mean Value of annual air quality monitoring results
2 - Total Suspended Particulate (Sum of preceding two columns)
3 - Geometric Mean Value of annual air quality monitoring results
4 National Ambient Air Quality Standards.

Table 3. Value functions and AQ_{dep} values for different sampling locations of Talcher coalfield

	SPM	SO_2	NOx	TSP×SO_2	Weighted AQi	AQ_{dep}	Rank
A1	0.15	0.98	0.9	0.699	6.787	-3.21	3
A2	0.19	0.981	0.899	0.56	6.977	-3.02	5
A3	0.01	0.98	0.93	1.386	5.407	-4.59	1
A4	0.04	0.972	0.898	1.22	5.498	-4.50	2
A5	0.23	0.992	0.91	0.436	7.175	-2.83	7
A6	0.24	0.99	0.921	0.456	7.397	-2.60	9
A7	0.47	0.998	0.948	0.259	8.106	-1.89	16
A8	0.29	0.99	0.932	0.332	7.448	-2.55	10
A9	0.52	0.99	0.95	0.249	8.223	-1.78	19
A10	0.26	0.992	0.928	0.391	7.308	-2.70	8
A11	0.5	0.999	0.945	0.273	8.063	-1.94	15
A12	0.44	0.98	0.933	0.319	7.789	-2.21	11
A13	0.24	0.99	0.918	0.518	7.153	-2.85	6
A14	0.38	0.998	0.941	0.406	7.957	-2.04	13
A15	0.14	0.991	0.928	1.01	6.905	-3.10	4
A16	0.44	0.99	0.938	0.228	8.339	-1.66	21
A17	0.42	0.99	0.93	0.286	8.241	-1.76	20
A18	0.38	0.992	0.927	0.3	8.124	-1.88	17
A19	0.4	0.99	0.93	0.342	7.975	-2.03	14
A20	0.4	0.992	0.939	0.362	7.941	-2.06	12
A21	0.48	0.99	0.921	0.25	8.189	-1.81	18

The air quality of Raghunathpur Village may be considered as the background status of Air Quality Depreciation as this location is free from any major air pollution sources.

While comparing with the Air Quality Depreciation Index data of other mining sites reported in other studies, it was found that index calculated was quite high as compared to other mining areas. In a study, Jharia was found to have the most degraded air quality status having index value upto -7.8 followed by Korba coalfield with a index value upto -5.94 (Singh, 2006). The highest index was calculated for the Raniganj coalfield with the index upto -3.31. So it can be inferred that the Talcher coal mine areas has a better air quality as compared to other mining areas.

4.0 Conclusions

The application of the proposed Air Quality Depreciation Index has shown that the index allows for more realistic air quality assessment as compared to interpretive evaluations that revolve around comparing observed concentrations to national ambient air quality standards. The Air Quality Depreciation index can be an invaluable tool to map periodic deterioration in air quality with respect to its potential for environmental damages. We believe that adoption of such an index to monitor air quality at all the mining locations in India will help mutual comparisons in a much more realistic and meaningful manner. This work is just a step in this direction. Since the air quality depreciation index is neither geographically specific nor constrained for the type or number of pollutants, it can be easily used for different situations and applications.

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