

Development of Environmental Quality Index for Environmental Sustainability and in Surface Mines in West Bengal

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Abstract: *Environmental quality index can be used as an indicator to monitor and regulate mining operations and ensure long-term environmental sustainability. It can be viewed as a mining footprint, which is surrogate of the environmental impacts of mining. In this paper, a methodological framework is developed to demonstrate how environmental quality index can be used as an indicator of environmental degradation.*

Keywords: Environmental, Sustainability indicator, GIS, PCA, Weights, West Bengal

1. Introduction

Environmental sustainability is defined as responsible interaction with the environment to avoid depletion or degradation of natural resources and allow for long-term environmental quality. The practice of environmental sustainability helps to ensure that the needs of today's population are met without jeopardizing the ability of future generations to meet their needs. Environmental sustainability is the ability to maintain the qualities of various environmental components, for example, air, water and soil. To monitor environmental sustainability, in and around a mining project, suitable indicators shall be designed. In my paper Environmental database are take two study areas.

Description of two study areas

Here author selects two study areas near by mining areas in West Bengal.

Database on environmental quality parameters

Two study areas are selected where big opencast mines are located. Several air, water and soil samples were collected from the strategic locations within the study areas. Strategic locations were selected within the active mining areas, and also in the surrounding villages. **Air quality survey**

Air quality (SPM and PM₁₀) parameters were collected from both the case study areas. Air quality stations were mostly located in the surrounding villages. Twenty air samples were collected and analyzed. PM₁₀, SPM concentration, in the ambient atmosphere, are analyzed. Air samples were collected at strategic locations where receptors were located. The receptors, in this case, were local villagers who were residing either in their native villages or at rehabilitation sites.. Air samples were mostly collected by installing high volume dust sampler on residential houses, community halls in villages around active mining areas and control villages. Twenty air samples were collected and concentration of PM₁₀ (µg/m³) and SPM (µg/m³) in the ambient atmosphere were analyzed. High volume dust sampler essentially consists of a blower and a filter and samples are collected for 24 hours. The high volume dust sampler was installed on roof top of residential houses, courtyards of houses, school buildings, community halls in different villages and around active mining areas. The filter papers were weighed to determine the dust deposited during the sampling period. The air flow rate was 1m³/ hour. Dust concentration was measured by dividing dust deposited on the filter paper over a period of 24 hours by the total air flow during that period. Descriptive statistics of the samples are given in following table.

Table 1: Descriptive statistics of air samples in study area 1

Parameter	No. of Samples	Mean	Standard Deviation	95% percentile value	5% percentile value	Permissible limit *
PM10	9	289.6	69.451	395.4	279	100
SPM	9	576.2	120.65	775.8	550	500

*Source: (MOEF, 2009 and CPCB, 1994)& National Ambient Air Quality Standard (2009)

Table 2: Description of air samples in study area 2

Parameters	No. of Samples	Mean	Standard Deviation	95% percentile value	5% percentile value	Permissible limit *
SPM	11	745.5	187.012	965.5	823	500 µg/m ³
PM10	11	397.82	107.946	547.5	323	100 µg/m ³

*Source: (MOEF, 2009 and CPCB, 1994)& National Ambient Air Quality Standard (2009)

Soil quality survey

Soil samples (NPK and organic matter) were collected from adjoining paddy fields in each village. In two case study areas forty – four soil samples were collected and analyzed. Four soil parameters, which are NPK and organic carbon are analysed. These soil quality parameters can be ameliorated by suitable soil treatment methods. Soil samples were collected using hand augers at two specific levels of the soil horizon, which was 15 cm and 30 cm.

Sampling locations selected includes paddy field adjacent to the villages and waste dumps created by mining. Available nitrogen concentration is measured by Kjeldahl method, phosphorous content in a soil sample is estimated by measuring colour intensity of molybdenum solution under spectrophotometer, using ammonium acetate. Soil solution potassium is measured under atomic absorption spectrophotometer and organic carbon is analysed by Walkley-Black chromic acid wet oxidation method.

Table 3: Soil fertility ratings

Sl. No.	Soil Nutrients	Soil Fertility Ratings		
		Low	Medium	High
1	Organic Carbon (%)	<0.5	0.5-0.75	>0.75
2	Available N (kg/ha)	<280	280-560	>560
3	Available P (kg/ha)	<10	10-24.6	>24.6
4	Available K (kg/ha)	<108	108-280	>280

Source: Department of Agriculture and Cooperation, Ministry of Agriculture, Government of India (2011)

Table 4: Descriptive statistics of soil samples (Study Area1)

Parameters	No of samples	Mean	Standard deviation	Low fertility standards
Organic Carbon (%)	26	0.53	0.12	< 0.5
Available nitrogen (Kg/ha)	26	63.77	21.7	< 280
Available potassium (Kg/ha)	26	227.36	116.02	< 108
Available phosphorous (Kg/ha)	26	63.37	12.60	< 10

Source-Manual prepared by faculty members of Burdwan University and T.D Biswas and S.K. Mukherjee (2009), Tata McGraw-Hill Publishing Company Limited.

Table 5: Descriptive statistics of soil samples (Study Area 2)

Parameters	No of samples	Mean	Standard deviation	Low fertility standards
Organic Carbon (%)	18	0.52	0.20	< 0.5
Available nitrogen (Kg/ha)	18	55.83	35.38	< 280
Available potassium (Kg/ha)	18	195.56	113.54	< 108
Available phosphorous (Kg/ha)	18	46.06	14.82	< 10

Source-Manual prepared by faculty members of Burdwan University and T.D Biswas and S.K. Mukherjee (2009), Tata McGraw-Hill Publishing Company Limited.

Results of soil samples, collected from two study areas, reveal low nitrogen content. Mean soil sample values show nitrogen content 55.83 kg/ha and 63.77 kg / ha in study areas 1 and 2 respectively; this value is very low as the threshold limit for low fertility is 280 kg /ha (Table 4 and 5)

2. Methodology

Step 1: Geographical Information System (GIS) using ILWIS 3.0

GIS software is used for spatial analysis. Principal Component Analysis (PCA) using STATA10 statistical software is applied to analyze different environmental quality parameters in the study area.

Step 2: Calculation of the areas of impact zones on the air and soil quality maps using GIS software. These land areas are footprints of the mining activities in the lease area.

Step 3: Actual mining area is where major mine facilities are located. The information on this area is available at the mine office.

Step 4: A ratio of mining footprint and the actual mining area is calculated. This ratio can be used as an indicator

Step 5: Under ideal condition, after mine closure, ecological footprints of mining should be zero and hence ecological indicator also becomes zero. High value of ecological indicator, that is, ratio of mining footprint by actual mining area, implies that large ecological footprints are left at the closing stage of a mine.

GIS maps

GIS maps are prepared showing impact zones where soil and air qualities are degraded. The impact zones, shown on the maps, are the footprints of mining in the area.

Air quality maps

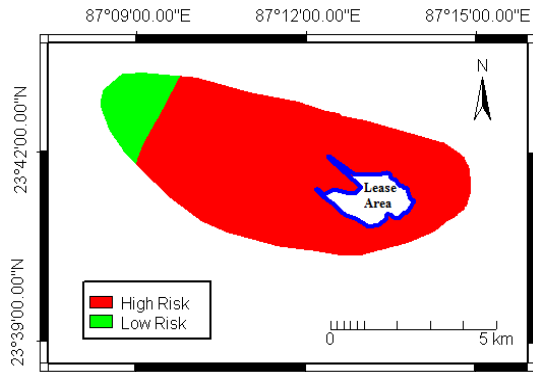


Figure 1

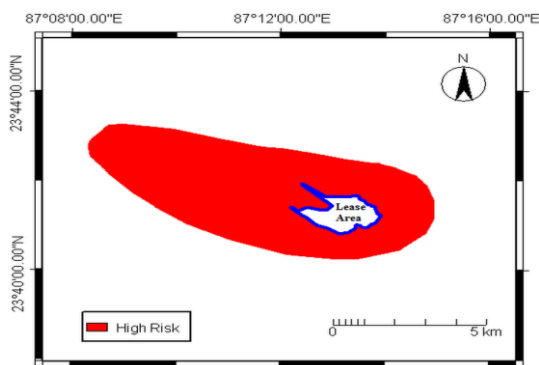


Figure 2

SPM (Study Area 1) PM₁₀ (Study Area1)

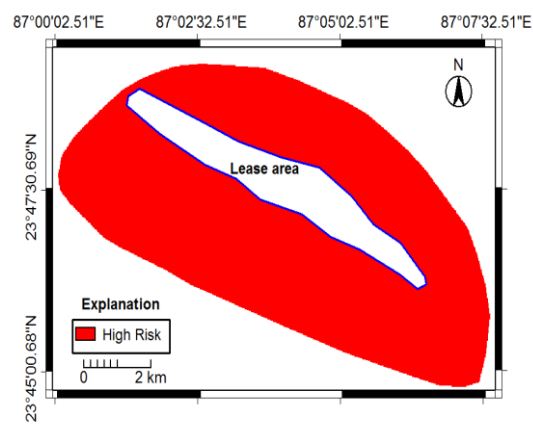


Figure 3

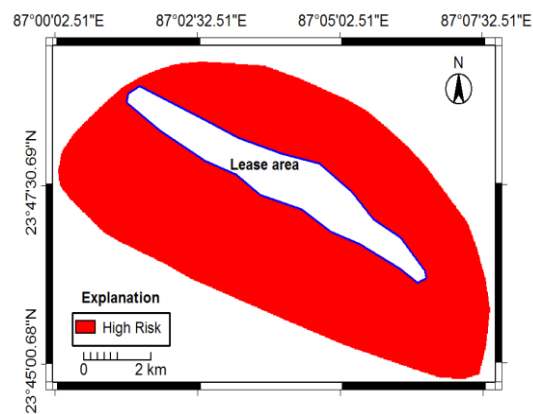


Figure 4

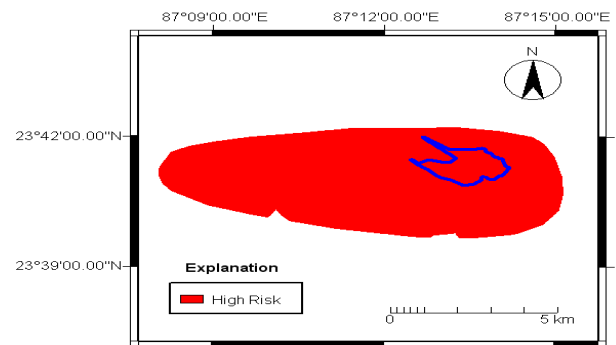
SPM (Study Area 2) PM₁₀ (Study Area 2)

GIS maps are prepared using different sample values of SPM and PM₁₀ concentrations in the ambient atmosphere (Figures 1 – 4). Both the maps have revealed high risk zones around the active mine sites. Permissible limits, shown in (Table2), are used as threshold values. This implies that the pixels having values higher than the prescribed limits (500µgm / m³ for SPM and 100µgm / m³ for PM₁₀) will be designated as high risk.

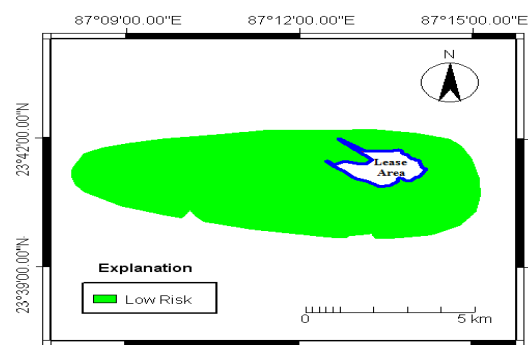
In all four maps (Figures 1 – 4.) the entire impact zones are shown as high risk areas, that is, above the permitted limit (Table 1). Further, the spatial data on these maps composite air quality maps for both the study areas can be developed. The purpose behind preparation of composite maps (air and soil) is demarcation of ecological footprints of mining in the region.

Soil Quality maps

Soil quality maps are prepared for (Nitrogen, Phosphorus, Potassium) NPK and organic carbon. These four soil quality components are analyzed because their deficiencies can be removed by adding fertilizer. The fertility ratings, in (Table4) are used to assign fertility status to the sample values that are interpolated at each pixel points.



**Figure: 6
(Study Area 1)**



**Figure: 5
Available Nitrogen Available Phosphorus (Study Area 1)**

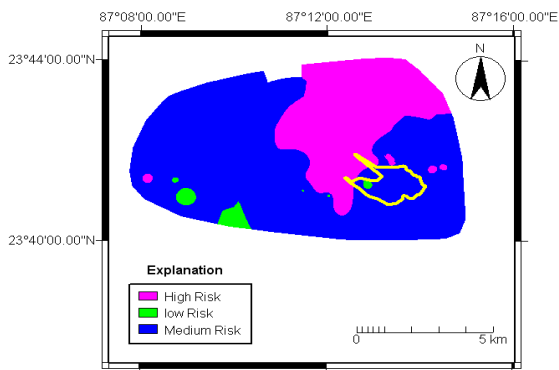


Figure: 7
(Study Area1)

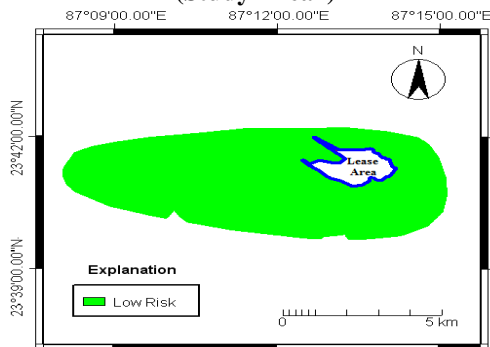


Figure: 8
Organic Carbon Potassium (Study Area1)

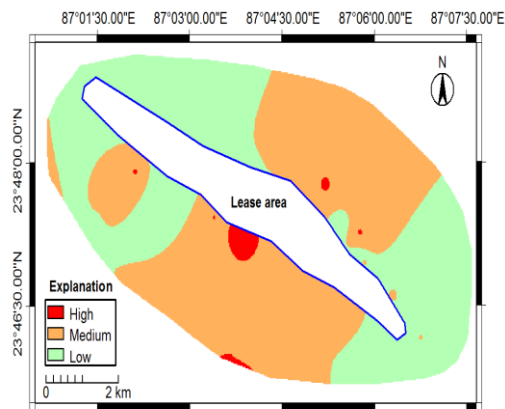


Figure: 9
(Study Area 2)

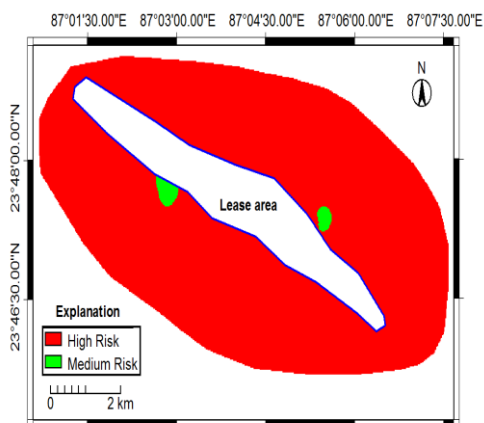


Figure: 10
Organic Carbon Phosphorous
(Study Area 2)

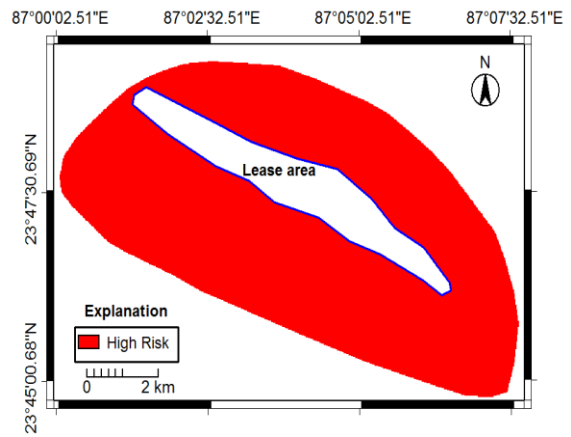


Figure 11
(Study Area 2)

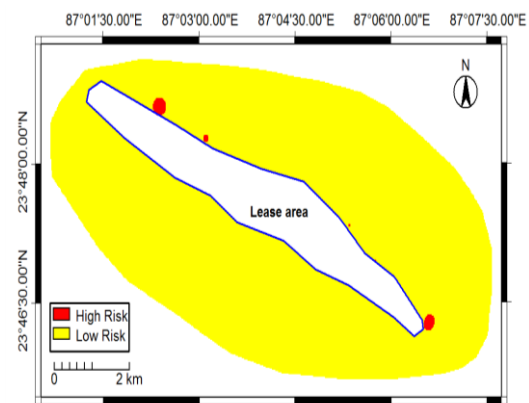


Figure12
Nitrogen Potassium
(Study Area 2)

The soil quality maps reveal deficiencies in soil nitrogen, phosphorus, potassium and organic carbon. For deficiency in the above soil quality parameters proper soil amelioration can be undertaken. By preparing these GIS maps during different time period, while the mine is in operation, fertility status of the soil in areas adjacent to the mine can be checked Management of nutrient status of the soil can be then done using the above map information about nutrient deficiency in soil. Ultimate aim behind preparation of GIS maps on individual soil quality parameters is preparation of composite soil quality maps, which can be used to demarcate impact zones that are actually mining footprints created by a mine.

Composite air quality maps

Composite air quality maps are prepared using the weight of air quality parameters.. To explain the process further few sample calculation on weight calculation are presented in Tables 7, 14 and equation (1). Composite air quality maps of two study areas (Figures 13 and 14).

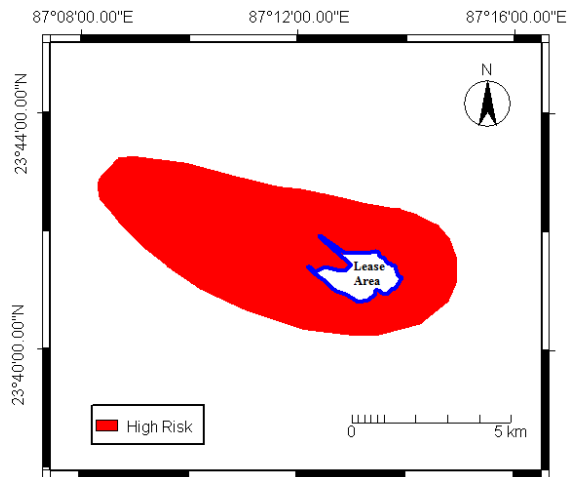


Figure 14
(Study Area 1)

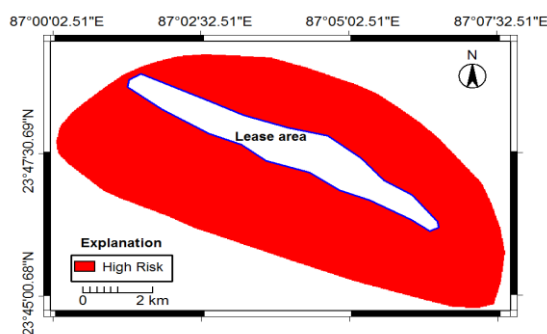


Figure 13
Composite air quality Composite air quality
(Study Area 2)

Ecology footprint (Air)

Principal Components Analysis (PCA) is carried out to investigate the factor loadings and weights of these indicators. Component 1 explains 98.3% of the variation in the database. Principal components (PCs) with Eigen values

greater than 1 (component 1) is selected (Table.7). The varimax rotation is employed to ensure that each variable is maximally correlated with one PC and had minimal associations with the other components (Kaiser, 1958). Weights of different air quality parameters are derived from eigen vectors of component 1, (Table 6 and 11)

Table 6: Eigen values principal components by PCA (Study Area 1)

Component	Eigenvalue	Difference	Proportion	Cumulative
Comp 1	1.86042	1.93431	0.9830	0.9836

Source: Prepared by researcher, by using primary data.

Table 7: Eigen values principal components PCA analysis (Study Area 2)

Component	Eigenvalue	Difference	Proportion	Cumulative
Comp1	1.87757	1.75514	0.9388	0.9388
Comp2	.122429	0.0612		1.0000

Source: Prepared by researcher, by using primary data.

Table 8: Weight of air quality parameters (Study Area 1)

Air quality parameters	Permissible limit*	Weights	Permissible limit multiplied by weight
PM ₁₀	100µgm / m ³	0.707	70.7
SPM	500µgm / m ³	0.707	354
Air quality index calculated on the basis of permissible limits (threshold limit)			424.7 µ gm /m ³

Source: (MOEF, 2009 and CPCB, 1994)

Air quality index is calculated for each pixels of the composite map with the help of following equation

Air quality index = Weight of PM₁₀ x Sample value of PM₁₀ + Weight of SPM x Sample value of SPM..... (1)

Threshold value of air quality index is calculated by the summation of the product of weights and permissible values ($0.707 \times 100 + 0.707 \times 500 = 424.7 = 425 \mu\text{g}/\text{m}^3$). Since this value is computed using permissible limits, stipulated by the government agencies, the derived value, that is, $425 \mu\text{g}/\text{m}^3$ is the threshold limit for air pollution. This is the threshold value above which the air quality index is considered as high risk. Air quality index is calculated for each sample point in

the combined map using the equation 1. A sample calculation on computation of air quality index in study area 1 is provided in (Table 8). The impacts zones are the ecological footprint of mining that shows land equivalent of air pollution around a mine site (Fig 15 & 16.). In Table 8 air quality indices are calculated at the sample points using equation 1.

Table 9: Mining footprint indicator (air) (Study Area 1)

Ecological footprint (Air quality)indicator	Area (Hectare)
Area under high risk	3534.63
Active mine working	461*
Ratio of high risk area with active mine working	7.7

Source: Prepared by researcher, by using primary data

*Active mining area include dumps, quarry, haul roads and siding etc. that can be measured from surface plan available at the mine office.

Table 10: Mining footprint indicator (air) (Study Area 2)

Ecological footprint (Air quality)indicator	Area (Hectare)
Area under high risk	65 00ha
Actual mine working	920 ha
Ratio of high risk area with active mine working	7.06

Source: Prepared by researcher, by using primary data

*Actual mining area include dumps, quarry, haul roads and siding etc. that can be measured from surface plan available at the mine office.

Ecological footprint (soil)

Weights of the soil parameters are derived by using PCA. In Table 16 two eigen values are above 1 are shown. Both

together can explain 76.6 % of the total variance. Table 11 shows the rotated component values of various soil parameters.

Table 11: Principal components on soil quality by PCA (Study Area1)

Components	Eigen values	Cumulative percentage
Components 1	2.22116	0.5553
Components 2	1.20842	0.7660

Weights of different soil parameters are calculated at (Table 12). A sample calculation of the weight of available phosphorus is given below Equation 2.

Table 12: Weights of different soil parameters by PCA (Study Area1)

Soil Parameters	Weights of the soil parameters
Available Phosphorous	$2.22116 \times 0.5834 + 1.20842 \times 0.0697 = 1.2912$
Organic Carbon	$2.22116 \times 0.4067 + 1.20842 \times 0.5499 = 1.5680$
Available Nitrogen	$2.22116 \times 0.3863 + 1.20842 \times 0.8313 = 1.8630$
Available Potassium	$2.22116 \times 0.5434 + 1.20842 \times 0.6524 = 1.9900$

Source: Prepared by researcher, by using primary data.

Weights of different soil parameters (Table 12) are calculated by multiplying 1st Eigen value with 1st Extracted Column Component [Examples: Available Phosphorous 2.22116 (1st Eigen value) \times 0.5834 (1st Extracted Column Component) + 1.20842 (2nd Eigen value \times 0.0697 (2nd Extracted Column Component, irrespective of sign negative

values are treated as positive value) = 1.2912]. -----
----- (2)

Medium fertility rating = $1.2912 \times 108 + 1.568 \times 0.5 + 1.863 \times 280 + 1.25 \times 10 = 674$ --- (3)

Table 13: Principal components (eigenvectors) (Study Area2)

Variable	Component 1	Component 2	Component 3	Component 4
Soil potassium	0.5068	-0.4037	-0.4064	0.6439
Soil phosphorous	0.4781	0.8389	0.1247	0.2284
Soil nitrogen	0.5150	-0.0285	-0.4669	0.7183
Soil organic carbon	0.4993	0.3640	0.7752	-0.3114

Source: Prepared by researcher, by using primary data

Using weightage derived in (Table 16) soil quality index is calculated.

$$\text{Soil quality Index} = 0.4993 * \text{Organic Carbon} + 0.4781 * \text{Phosphorous} + 0.5068 * \text{Potassium} + 0.5150 * \text{Nitrogen} = 203.965 \text{ ----- (4)}$$

Composite maps of study areas 1 and 2 are prepared using threshold value given in equation 3 and 4 respectively. At each pixel the value of soil quality index is calculated and checked with threshold values. If soil quality index at a pixel is lower than the threshold value then the rating at that pixel is low fertility. Low fertility zone is shown as high risk in the figures given below.

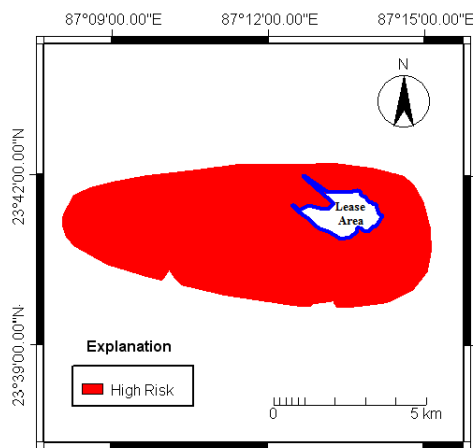


Figure 15 (Study Area 2)

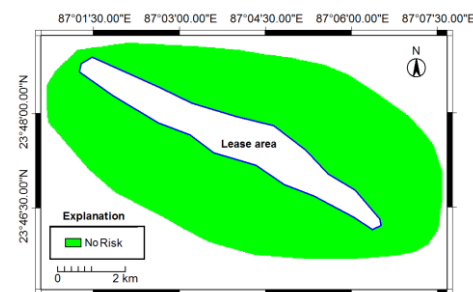


Figure 16

Table 16: Mean and Percentile of PM₁₀ (Study Area1)

Parameters	No. of Samples	Mean	Standard Deviation	95% percentile value	5% percentile value	Permissible limit *
PM ₁₀	9	289.55	69.451	395.4	279	100

* Source: MOEF Notification dated 16.09.2009 GSR 826 (E)

Table 17: Mean and Percentile values of air quality samples (Study Area 2)

Parameters	No. of Samples	Mean	Standard Deviation	95% percentile value	5% percentile value	Permissible limit
SPM	9	576.222	120.6459	775.8	550	500

Source: MOEF Notification dated 16.09.2009 GSR 826 (E)

At this stage a new concept termed as exceedance factor is introduced. It is the ratio of annual (or 24-hour) mean concentration of a pollutant by the prescribed limit. The Exceedance Factor (EF) is calculated as follows:

Composite Soil quality fertility Composite Soil quality fertility (Study Area 1)

Ecological Indicator (Soil)

Based on the information provided by maps (Fig 15 and 16) the ecological footprints of mining are calculated. Using the data collected from different mines on actual mining areas ecological footprint indicators is calculated. In study areas 1 and 2 ecological footprint indicators are 7.8 and 6.05 respectively.

Table 14: Ecological footprint indicator (Soil quality) (Study Area 1)

Ecological footprint (Soil Quality) indicator	Area(Hectare)
Area under high risk(degradation of soil quality)	3613.34
Actual Mining Area	461*
Ratio high risk area with actual mining working	7.8
Level of soil Degradation	High

*Actual mining area includes dumps, quarry, haul roads and siding etc that can be measured from surface plan available at mine office.

Source: Prepared by researcher, by using primary data

Table 15: Ecological footprint indicator (Soil quality) (Study Area 2)

Ecological footprint (Soil quality) indicator	Area (Hectare)
Area under high risk	5570 ha
Actual mine Area	920 ha
Ratio of high risk area with active mine working	6.05
Fertility status	

*Actual mining area include dumps, quarry, haul roads and siding etc that can be he ratio of Air and Soil is given below.

Indicators based on ratios and percentiles

Indicators are developed by spatial data analysis using GIS maps. In this subsection further statistical data analysis is done. Table 16 and 17 gives mean, standard deviation and different percentile values of air quality sample results.

$$\text{Exceedance factor} = \frac{\text{Observed mean concentration of criteria pollutant}}{\text{Prescribed standard for the respective pollutant}} \text{ ----- (5)}$$

The ambient environmental quality has been categorized (CPCB) into four broad categories based on an exceedance factor

Table 18: Exceedance factors and respective pollution level

Pollution Level	Exceedance factor
Critical pollution	more than 1.5
High pollution	between 1.0 and 1.5
Moderate pollution	between 0.5 and 1.0
Low pollution	less than 0.5

Source-Manual prepared by faculty members of Burdwan University and T.D Biswas and S.K. Mukherjee (2009), Tata McGraw-Hill Publishing Company Limited.

Table 19: Exceedance factor

No of samples	Mean	Prescribed Limit	Exceedance factor	Pollution level
9	576.222	500 µg/m ³	1.152	High
9	289.5556	100 µg/m ³	2.9	Critical

Source-Manual prepared by faculty members of Burdwan University and T.D Biswas and S.K. Mukherjee (2009), Tata McGraw-Hill Publishing Company Limited.

Indicators can be also framed as shown in (Table 20)

Table 20: Relevant Indicators

No. of Samples	Mean	Prescribed limit	Indicator1	Indicator2	Indicator3
			95% percentile/5% percentile	95% percentile /Standard value	5% percentile /Standard value
9	576.222	500 µg/m ³	1.410	1.551	1.1
9	289.555	100 µg/m ³	1.417	2.636	2.79

Source-Manual prepared by faculty members of Burdwan University and T.D Biswas and S.K. Mukherjee (2009), Tata McGraw-Hill Publishing Company Limited.

Indicator 1, the range ratio, is computed by dividing value at predetermined percentile by predetermined lower percentile, in this case 95 percentile and 5 percentile respectively. Indicator 2 determines exceedance from standard value and predetermined high. Similar comparison can be done low percentiles. Using both these indicators it is found that air quality in study area 1 is cortically polluted.

how many more pebbles you will place to demonstrate the present pollution level

Indicator based on Likert scale

Scoring by using Likert scale

The villagers are asked to express their perceptions on environmental degradation by scoring using Likert scale from 1 to 10. Example: The villagers are asked “You are given ten pebbles. How many pebbles you will place for level of pollution when there was no mining activity? With mining activities, in the region, if the pollution has increased

The score cards of the villagers are shown in tabular form. Tables are prepared using villager’s perception on changes of environmental quality from pre mining to post mining period. At this stage a new factor is introduced called impact factor. Impact factor is the ratio of the score assigned by the respondents for environmental quality in pre mining phase against that in post mining phase. Example: Villagers may assign a score of two for level of air quality degradation in pre mining phase and eight during mining phase, during operational phase of a mine. Impact factor in this case is four. Using impact factor PCA is run to find the weightage of each impact. Principal components/correlation

Table 21: Principle component on villager’s perception

Component	Eigenvalue	Difference	Proportion	Cumulative
Comp1	1.53486	0.416851	0.3070	0.3070
Comp2	1.11801	0.117158	0.2236	0.5306
Comp3	1.00086	0.27283	0.2002	0.7307
Comp4	0.728025	0.109784	0.1456	0.8764
Comp5	0.618242	-	0.1236	1.0000

Source: Prepared by researcher, by using primary data.

Table 22: Principal component results on villager’s perception

Variable	Comp1	Comp2	Comp3	Comp4	Comp5	Unexplained
Water pollution	-0.2627	0.7732	-0.1773	0.2643	0.4815	0
Air pollution	0.5789	-0.616	0.0268	0.8124	-0.0213	0
Dust disease	0.4093	0.6301	0.2399	-0.2663	-0.5541	0
Water disease	0.6269	-0.0340	0.0308	-0.4333	0.6459	0
Water depletion	-0.1883	-0.0120	0.9536	0.1073	0.2087	0

Source: Prepared by researcher, by using primary data

The components with eigen value > 1 are selected. Three components are selected and the scores of each variable are obtained. An environmental index can be derived using the following relationship.

Sample calculation for weight of water pollution

Environmental quality index

= 1.144 x Impact factor for dust related diseases + 1.567 x Impact factor for air pollution + 1.44 x Impact factor for water pollution + 1.257x Impact factor for water availability + 1.03 x Impact factor for water borne diseases.

Sources of data: In this paper all the data are primary data, which collected by researches from surface mines in West Bengal (Study already described in above part of this paper.) for the purpose of research. This data have a copy rights for the university, it is not to be shared.

References

- [1] Allgaier, F. K. (1997). Environmental effects of mining. In J. J. Marcus (Ed.), *Mining and environmental handbook: Effects of mining on the environment and the environmental controls on mining*. London: Imperial College Press.
- [2] Chen, B., & Chen, G. Q. (2007). Modified ecological footprint accounting and analysis based on embodied exergy - A case study of the Chinese society 1981–2001.
- [3] *Ecological Economics*, 61(2–3), 355–376. Chen, B., Chen, G. Q., Yang, Z. F., & Jiangc, M. M. (2007). Ecological footprint accounting for energy and resource in China. *Energy Policy*, 35(3), 1599–1609.
- [4] CPCB (Central Pollution Control Board). (1994). [www.cpcb.nic.in/.../\(10\)%20Air%20\(P&CP\)Rules1983%20Notifications](http://www.cpcb.nic.in/.../(10)%20Air%20(P&CP)Rules1983%20Notifications).
- [5] Davis, J. C. (1973). *Statistics and data analysis in geology*. New York: Wiley.
- [6] Frelich, L. E. (2014). Forest and terrestrial ecosystem impacts of mining. The University of Minnesota Center for Forest Ecology. https://www.savetheboundarywaters.org/sites/default/files/public/attachments/frelich_2014__report_september_22_2014.pdf.
- [7] Galli, A., Kitzes, J., Wermer, P., Wackernagel, M., Niccolucci, V., & Tiezzi, E. (2007). An exploration of the mathematics behind the ecological footprint. *International Journal of Ecodynamics*, 2(4), 250–257.
- [8] Ghosh, A. K. (1990). Mining in 2000 AD—Challenges for India. *Journal Institution of Engineers (India)*, 39(ii), 1–11.
- [9] Gilpin, Alan. (1996) *Dictionary of Environment and Sustainable Development*, Chichester, John Wiley and Sons.
- [10] Hsu, A., et. al. (2014) *Environmental Performance Index* New Haven, CT: Yale, Center for Environmental Law & Policy.
- [11] James, P. (1994) *Business Environmental Performance Measurement*. *Business Strategy and the Environment*, 3(2), 59-67.
- [12] Jonson, R. A., & Wichern, D. W. (2006). *Applied multivariate statistical analysis* (5th ed.). Englewood Cliffs: Prentice Hall.
- [13] Kaiser, H. F. (1958). The varimax criterion for analytic rotation in factor analysis. *Psychometrika*, 23(3 September), 187–200.
- [14] Ministry of Agriculture. (2011). *Methods manual soil testing in India*. New Delhi: Department of Agriculture & Cooperation, Ministry of Agriculture, Government of India.
- [15] MOEF (Ministry of Environment and Forest). (2009). <http://envfor.nic.in/legis/ep/826.pdf>. Monfreda, C., Wackernagel, M., & Deumling, D. (2004). Establishing national natural capital accounts based on detailed Ecological Footprint and biological capacity assessments. *Land Use Policy*, 21, 231–246.
- [16] Morford, S. (2007). A review of social indicators for land use planning in British Columbia. https://www.for.gov.bc.ca/tasb/slrp/lrmp/nanaimo/central_north_coast/docs/social_indicators_final_200708.pdf.
- [17] Nas, B., & Berktaay, A. (2010). Groundwater quality mapping in urban groundwater using GIS. *Environment Monitoring Assessment*, 160, 215–227.
- [18] National Environmental Policy, (2006) available in website <http://www.envfor.nic.in/nep/nep2006e.pdf>.
- [19] National Ambient Air Quality Standards, (2009) Gazette Notification No 217 18 November 2009.
- [20] Niemi, J. G., & McDonald, M. E. (2004). Application of ecological indicators. *Annual Review of Ecology Evolution and Systematics*, 35, 89–111