ENVIRONMENTAL POLLUTION POTENTIAL RANKING OF INDUSTRIES USING EVAMIX APPROACH: A CASE STUDY

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Abstract : Environmental pollution remains a serious issue in the developing world, affecting the lives of billions of people, reducing their life expectancy and damaging children's growth and development. The problem of pollution and its corresponding adverse ecological impacts have been aggravated due to increasing industrial and other developmental activities. India, among other developing nations of the world, is facing the challenge of industrial pollution at an alarming rate. This has made the constant surveillance of environmental characteristics a necessary task. There is an urgent need to identify critically polluted industries and identifying their problematic dimensions. For this purpose, an attempt has been made to address the problem, and a viable procedure named EVAMIX has been proposed for ranking of industries based on their environmental pollution potential.

***IndexTerms* - Environmental Pollution, Multi-criteria Decision Making, Integrated EVAMIX approach, Ranking of Industries.**

I. INTRODUCTION

Critically polluted industries are not only environmental challenges but they are also public health challenges. Indeed, only a fraction of national/international efforts have been made, so far, for remediation of such critically polluted industries, despite their significant threat to environmental and public health. The environmental pollution index (CEPI) helps in quantifying the environmental effect of the critically polluted industries by synthesizing available information on environmental status by using quantitative criteria.

To accomplish this, it is required, at the first instance, to process base level information and develop a methodology for identification and ranking of the selected industries based on various dimensions of pollution.

An effort has been made to formulate a model employing EVAMIX (Evaluation of Mixed Data) approach, with a view to rank industries based on their water and air pollution index which quantify the environmental effect.

Pollution load in air and water is not just an environmental challenge, but synergistically a public health challenge as well. There is an urgent need to classify polluted industries based on scientific criteria. EVAMIX (Evolution Matrix) is a matrix based multi-criteria evaluation method that makes use of both quantitative and qualitative criteria within the same evaluation, regardless of the units of measure. Although this feature appears to exist in several other similar methods, upon closer examination it becomes clear that most methods either deal with quantitative criteria as if they are qualitative or qualitative criteria as if they are quantitative. In either case, the evaluation process is distorted. The algorithm behind EVAMIX maintains the essential characteristics of quantitative and qualitative criteria, yet is designed to eventually combine the results in a single appraisal score. This unique feature gives the method much greater flexibility than most other matrix based evaluation methods, and allows the evaluation team to make use of all data available to them in its original form. Finally, two numerical examples are used to illustrate the use of the proposed method.

II. ENVIRONMENTAL POLLUTION: NEEDS & RELEVANCE

The establishment of pollution control policies and the setting of legal standards on emissions is an imperfect art. Frequently, at the time decisions are to be made, all the information may not be available and cannot be obtained. Historically pollution sources are grouped according to the part of environment most affected. The main categories of pollution are as follows: air, water and land pollution. This concept of categorizing of pollution was more appropriate at the time of pre-industrialization era when the pollution assimilation capacity of the environment was highest.

In present time of industrialization when the natural environmental resources have been gradually converted in to highly polluted dumpsites, this traditional approach needs to be rejected and be recognized in the unity of forms of pollution. The unity concept of pollution is more appropriate to be applied rather than individualistic approach as practiced today. Therefore, this study focuses on evolving a methodology to develop an integrated environmental pollution index, which will provide an effective tool to study the integrated pollution potential of an industry.

2.1 Multi criteria Decision Making

MCDM is a structured (organized) approach to decision making. Values, beliefs and perceptions are the force behind almost any decision-making activity. They are responsible for the perceived discrepancy between the present and a desirable state.

Decision-makers are typically required to consider multiple, often conflicting, objectives in making decisions. MCDM models are suitable for handling such decision problems. The general discussion of the particular MCDM models, the Analytical Hierarchy Process (AHP) is given in the following section of "Selection of MCDM Models."

2.2 Selection of MCDM Models

It is generally accepted, how-ever, that no single method is likely to produce the "right" solution. Hence, it is prudent to utilize more than one method in practical applications. The choice between alternative models is based on their performance judged in terms of a number of criteria. The selection of the models is based on the following evaluation criteria like

- Internal consistency and logical soundness;
- Transparency;
- Ease of use;
- Data requirements are consistent with the importance of the issue being considered;
- Realistic time and manpower resource requirements for the analytical process;
- Ability to provide an audit trail; and
- Software availability, where needed.

2.3 The Analytical Hierarchy Process

Saaty developed the AHP in the 1970s as a way of organizing information and judgments in selecting preferred alternatives in decision-making problems. AHP is especially suitable for complex decisions that involve the comparison of decision elements that are difficult to quantify. It is based on the assumption that when faced with a complex decision, the natural human reaction is to cluster the decision elements according to their common characteristics. It involves building a hierarchy structure of decision elements and then making pair wise comparisons of decision criteria. The identified decision criteria are prioritized and grouped. The most important criteria are grouped at the highest level, with sub-criteria that further defined each parent criterion grouped at successively lower levels. Structuring the criteria that are important in making decisions is an essential feature in the decision making process.

AHP is a widely used MCDM model specifically designed for decisions that require the integration of quantitative data with less tangible qualitative considerations, such as values and preferences. It has the advantage of being able to handle qualitative data by pair wise comparison, and uses relatively simple method to calculate decision scores.

2.1.1. Integrated EVAMIX approach

The reasons behind considering the EVAMIX approach for ranking the industries are as follows:

- Assessment of final ranking of industries in terms of quantum of pollution load emitted by industries by pair-wise comparisons of industries.
- Industries under consideration are clearly defined (less polluting and more polluting).
- Can handle both quantitative and qualitative values of pollution parameters.
- Synthesis of priorities of the industries by criteria is carried out into composite measures to arrive at a set of ratings for the industries.
- Priorities underlying the evaluation are made explicit, and can be flexibly applied to highlight the effect that weighting has on the final ranking.

In present paper, integration of AHP is done with the purpose to provide a vector of weights which expresses the relative importance of industries. AHP method provides assessment and evaluation by pair wise comparison for the decision makers'. With the help of maximum eigenvector, priorities of pollution parameters and industries can be calculated. The set of ranking for the industries can be done by the priorities of their pollution parameters.

Initially, Voogd established Evaluation of Mixed Data (EVAMIX) method, which was later-on advocated by Martel and Matarazzo. The main reason behind the EVAMIX approach is that it handles both qualitative and quantitative data.

The procedure of EVAMIX method consists of the seven steps and discussed in next section. EVAMIX method commences by identifying criterion-to-criterion (unique pairs) pollution parameter of industries. The degree of pair-wise dominance for each pair of industries is calculated, as the difference in score received by the least polluting industry compared to the most polluting industry. The weighted sum of the dominance scores is then assigned to each industry.

Step I: First a set of industries is identified. Then, various pollution parameters and industries are short listed to find out the most polluting and least polluting industries amongst given set of industries. Using this information construct a data matrix of (m x n) size. Where n is number of industries and m is the number of relative pollution parameter chosen to find most polluting industries. Next step is to distinguish the ordinal and cardinal pollution parameter out of decision matrix.

Step II: Normalizing the data set is done in the range of 0 – 1 using linear normalization procedure. The less polluting and more polluting pollution parameter are weighted by different equations. For beneficial pollution parameter, normalize the decision matrix using the following equation:

For less polluting pollution parameters normalize the decision matrix using following equation:

$$r_{ij} = [x_{ij} - \min(x_{ij})] \,/\, [\max(x_{ij}) - \min(x_{ij})] \text{ (i=1,2,3, … m, j=1,2,3, … n)} \quad (2.1)$$

For more polluting pollution parameters, the above equation can be rewritten as:

$$r_{ij} = [\max(x_{ij}) - x_{ij}] \,/\, [\max(x_{ij}) - \min(x_{ij})] \text{ (i=1,2,3, … m, j=1,2,3, … n)} \quad (2.2)$$

According to (1) and (2) in the normalized decision matrix maximum value will always 1 and minimum value equal to 0.

Step III: Calculate the evaluative differences of i^{th} industry on each ordinal and cardinal criterion with respect to other industries. This step involves the calculation of differences in pollution parameter values between different industries pair-wise. Pair-wise is done based on Analytic Hierarchy Process (AHP) Saaty and Xu. It provides a way of breaking down the general data into a hierarch of sub-data, which are easier to evaluate. These comparisons may be taken from actual measurements or from a fundamental scale which reflects the relative strength of preferences introduced by Fechner and further advocated by Turstone.

In the pair-wise comparison method, pollution parameter and industries are presented in pairs. It is necessary to evaluate individual industries. An attribute compared with it is always assigned the value 1, so the main diagonal entries of the pair-wise comparison matrix are all 1. The numbers 3, 5, 7, and 9 correspond to the verbal judgments "moderate importance", "strong importance", "very strong importance", and "absolute importance" (with 2, 4, 6, and 8 for compromise between these values). The judgments are given using fundamental scale of AHP.

Let A=[a_{ij}] for all I,j = 1,2, … , n (a_i Vs a_j) denote a square pair-wise comparison matrix. Each entry in the matrix A is positive (a_{ij}> 0) and reciprocal (a_{ij}= 1/ a_{ij} where i,j = 1,2, … , n). Using geometric mean method; weights are calculated by following steps.

Find the relative normalized weight (w_j) of each pollution parameter by geometric means of rows in matrix A= [a_{ij}] and represent by A_1.

Calculate matrices $A_2$and A_3 .

where, A_2= A x A_1 and A_3 = A_2/A_1,

Where A1 = [$w_1, w_2, \dots , w_j$]^T

Determine the maximum Eigen value λ_{max} that is the average of matrix A_3.

Calculate the consistency index

$$CI = (\lambda_{max} - m)/(m - 1) \qquad (2.3)$$

The smaller the value of CI, the smaller is the deviation from the consistency.

Obtain the random index (RI) for the number of pollution parameter used in decision making by T. L. Saaty. (2000).

Calculate the consistency ratio CR = CI/RI. Usually, a CR of 0.1 or less is considered as acceptable, and it reflects an informed judgment attributable to the knowledge of the analyst regarding the problem under study.

Step IV: Compute the dominance scores of each industry pair (*i, i'*) for all the ordinal and cardinal criteria using the following equations:

$$\alpha_{ii'} = [\sum_{j \in O}\{W_j sgn(r_{ij} - r_{i'j})\}^c]^{1/C} \qquad (2.4)$$

Where

$sgn(r_{ij} - r_{i'j})$ = + 1 if $r_{ij} > r_{i'j}$

= 0 if $r_{ij} = r_{i'j}$

= - 1 if $r_{ij} < r_{i'j}$

$\gamma_{ii'} = [\sum_{j \in C}\{W_j sgn(r_{ij} - r_{i'j})\}^c]^{1/C}$

The symbol c denotes an arbitrary scaling parameter, for which any arbitrary positive odd number, like 1, 3, 5… may be chosen, O and C are the sets of ordinal and cardinal criteria respectively, and $\alpha_{ii'}$ and $\gamma_{ii'}$ are the dominance scores for industry pair, (i ,i') with respect to ordinal and cardinal criteria respectively. It is assumed that the value of c for qualitative evaluation $\alpha_{ii'}$ is taken equal to 1. Evidently, all standardized scores should have the same direction, i.e., a "higher" score should imply a "large" preference. It should be noted that the scores $\gamma_{ii'}$ of the quantitative criteria also have to represent "the higher, the better".

Step V: Since $\alpha_{ii'}$ and $\gamma_{ii'}$will have different measurement units, a standardization into the same unit is necessary. The standardized dominance scores can be written as:

$$\delta_{ii'} = h(\alpha_{ii'}) \text{ and } d_{ii'} = h(\gamma_{ii'}).$$

where h represents a standardization function. The standardized dominance scores can be obtained using three different approaches, i.e., (a) subtractive summation technique, (b) subtracted shifted interval technique, and (c) additive interval technique. The standardized ordinal score ($\delta_{ii'}$) and cardinal dominance score ($d_{ii'}$) for the industry pair, (*i, i*') using additive interval technique is calculated by following equations:

Standardized ordinal dominance score

$$\delta_{ii'} = \left(\frac{\alpha_{ii'} - \alpha^-}{\alpha^+ - \alpha^-}\right) \qquad (2.5)$$

where α^+(α^-)is the highest (lowest) ordinal dominance score for the industry pair, (*i,i'*).

Standardized cardinal dominance score

$$d_{ii'} = \left(\frac{\gamma_{ii'} - \gamma^-}{\gamma^+ - \gamma^-}\right) \qquad (2.6)$$

where γ^+(γ^-)is the highest (lowest) cardinal dominance score for the industry pair, (*i,i'*).

Step VI: Let us assume that weights w_j have quantitative properties. The overall dominance measure $D_{ii'}$ for each pair of industries (*i.i'*) is:

$$D_{ii'} = w_o \delta_{ii'} + w_c d_{ii'} \qquad (2.7)$$

where w_o is the sum of the weights for the ordinal criteria

$w_O = \sum_{j \in O} w_j$

and w_c is the sum of the weights for the cardinal criteria

$w_C = \sum_{j \in C} w_j$

This overall dominance score reflects the degree to which industry a_i is less polluting or more polluting compared to industry $a_{i'}$ for the given set of attribute and the weights. In general the measure $D_{ii'}$ may be considered as function K of the constituent appraisal scores: $D_{ii'}$ = k (s_i , $s_{i'}$). This expression represents a well-known Pairwise comparison problem. Here for each pair $D_{ii'} + D_{i'i} = 1$.

Step VII: Calculate the appraisal score. The appraisal score for i^{th} industry (S_i) is computed which gives the final preference for a given list of industries. Higher the appraisal score better is the performance of the industries. The best industry is one which has the highest value of the appraisal score. Appraisal score

$$S_i = \sum_{i'}\left(\frac{D_{i'i}}{D_{ii'}}\right)^{-1} \qquad (2.8)$$

The methodology proposed in this paper enables the decision maker to rank the industries from least polluting to the most polluting amongst given set of industries. The method is able to deal with any number pollution parameter and industries by effective mathematical steps. In order to demonstrate and validate the applications of the combined EVAMIX method for industrial environment, following two examples are illustrated.

2.1.2. Case study

The case study relates to the available air and waste water characteristics from three chemical industries and three thermal power station units located in Gujarat state, India. Table 1 shows the effluent characteristics of the treated waste water and the stack emissions for above mentioned industries monitored for winter (M_1), summer (M_2), and rainy season (M_3).

Table 1 : Effluent characteristics of wastewater and stack emissions.

Sub Criteria	GPCB	Industry 1			Industry 2			Industry 3		
	limit	M_1	M2	M3	M1	M2	M3	M1	M2	M3
SS, mg/l	100	114.0	95.0	65.0	75	85	50	20	30	40
TDS, mg/l	2100	4500	4225	4775	2175	2640	2591	1110	1200	1235
COD, mg/l	250	75	85	99	88	110	125	89	60	50
BOD, mg/l	30	25	29	31	45	35	32	20	25	18
Chlorides, mg/l	600	275	350.61	500.25	90	125	150	750	100	250
Sulphates, mg/l	1000	1610	1375	1590	0.26	0.00	1.5	600	550	475
Phosphates, mg/l	5	0.00	0.00	0.00	6.0	3.45	6.5	0.00	0.00	0.00
SO_X, ppm	100	12.25	13.12	3.4	61.9	80.0	110	15.0	25.0	45.0
NO_X , ppm	50	21.5	30.0	36.0	58.0	49.0	55.0	14.0	35.0	36.0
SPM, mg/Nm^3	150	60.0	55.0	80.0	20.0	175	60.0	175	220	159
Cl_2, mg/Nm^3	9	4.5	3.66	3.91	0.00	0.00	0.00	0.00	0.00	0.00
HCl, mg/Nm^3	20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
SS, mg/l	100	16.0	34.0	30.0	57	46	38	32.4	30	28
TDS, mg/l	2100	790	740	812	1054	844	840	876	804	836
BOD, mg/l	30	15.4	18.0	14.0	12	14	14	0.00	0.00	0.00
Phosphates, mg/l	5	2.68	0.97	1.40	1.41	0.98	1.04	0.418	0.700	1.12
Oil & grease ,mg/l	10	1.4	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total chromium, mg/l	2	0.014	0.012	0.012	0.018	0.012	0.013	0.014	0.012	0.012
Iron, mg/l	1	0.032	0.026	0.028	0.042	0.034	0.032	0.034	0.028	0.032
SO_X, ppm	100	3.61	6.22	12.25	12.23	9.21	6.1	4.80	4.20	6.1
NO_X, ppm	50	7.21	6.40	10.4	140	140	132	7.90	7.40	7.20
SPM, mg/Nm^3	150	0.00	7.00	3.8	3.6	3.1	2.4	0.00	0.00	0.00

Example 1: The EPPI was developed for three chemical industries having three seasonal monitored emission data as given in table 1.

Score using pollution parameter of air: First decision matrix is formed and it is shown below. Here the decision matrix is calculated by taking the average of the three seasonal data.

Table 2 : Decision Matrix for three chemical industries (air pollutants)

Industries	**Pollutants**			
	SO_X	**NO_X**	**SPM**	**Cl_2**
Industry1	9.59	29.1667	65	4.0233
Industry2	83.9667	54	85	0
Industry3	28.3333	28.3333	184.6667	0

The normalized decision matrix for polluting (contagious) pollution parameter is calculated.

Table 3 : Normalized decision matrix for three chemical industries (air pollutants)

Industries	**Pollutants**			
	SO_X	**NO_X**	**SPM**	**Cl_2**
Industry 1	1.0000	0.9673	1.0000	0.0000
Industry 2	0.0000	0.0000	0.8324	1.0000
Industry 3	0.7481	1.0000	0.0000	1.0000

The weights are 0.222, 0.203, 0.221, and 0.187 for SO_X, NO_X, SPM and Cl_2 respectively. Now calculate the dominance scores of each industry over other industries, industry pair, for all pollution parameter. All pollution parameter considered as cardinal pollution parameter.

Table 4 : Dominance scores for three chemical industries (air pollutants)

Pair	$\gamma_{ii'}$	Pair	$\gamma_{ii'}$
(1,2)	0.4590	(2,3)	-0.2040
(1,3)	0.0530	(3,1)	-0.0530
(2,1)	-0.4590	(3,2)	0.2040

The standardized dominance scores for each industry pair for all pollution parameter.

Table 5 : Standardized dominance scores for three chemical industries (air pollutants)

Pair	$d_{ii'}$	Pair	$d_{ii'}$
(1,2)	1.0000	(2,3)	0.2778
(1,3)	0.5577	(3,1)	0.4423
(2,1)	0.0000	(3,2)	0.7222

The Overall Dominance score of each industry pair for all pollution parameter

Table 6 : Overall dominance scores for three chemical industries (air pollutants)

Pair	$D_{ii'}$	Pair	$D_{ii'}$
(1,2)	0.8330	(2,3)	0.2314
(1,3)	0.4646	(3,1)	0.3684
(2,1)	0.0000	(3,2)	0.6016

The final Appraisal Score of three chemical industries for air pollutants

Table 7 : Final Appraisal scores for three chemical industries (air pollutants)

Alternatives	Industry 1	Industry 2	Industry 3
Appraisal Score	1.2611	0.3846	0.6076

In EVAMIX approach we are converting all pollution parameter into less contagious pollution parameter weather the pollution parameter is contagious or less contagious. While normalizing less contagious pollution parameter we can see that the attribute which have higher value is converted in to maximum value, i.e. 1. And while normalizing contagious pollution parameter we can see that the attribute which have higher value is converted in to minimum value, i.e. 0. As all pollution parameter are converted into less contagious pollution parameter to the industry, higher the appraisal score better the industry. So by looking at the appraisal score of three chemical industries we can say that industry 1 is better than industry 2 and industry 3.

Score using pollution parameter of water: First decision matrix is formed and it is shown below. Here the decision matrix is calculated by taking the average of the three seasonal data.

Table 8 : Decision matrix for three chemical industries (water pollutants)

Industries	Pollutants							
	SS	TDS	COD	BOD	Chlorides	Sulphates	Phosphates	Bio-assay
Industry1	91.333	4500	86.3333	28.3333	375.287	1525	0	0.7
Industry2	70	2468.667	107.6667	37.3333	121.6667	0.5867	5.3167	0.6167
Industry3	30	1181.667	66.3333	21	366.6667	541.6667	0	0.9833

The normalized decision matrix for less contagious and contagious pollution parameter for all industries

Table 9 : Normalized decision matrix for three chemical industries (water pollutants)

Industries	Pollutants							
	SS	TDS	COD	BOD	Chlorides	Sulphates	Phosphates	Bio-assay
Industry1	0.0000	0.0000	0.5162	0.5511	0.0000	0.0000	1.0000	0.2222
Industry2	0.3478	0.6122	0.0000	0.0000	1.0000	1.0000	0.0000	0.0000
Industry3	1.0000	1.0000	1.0000	1.0000	0.0340	0.6451	1.0000	1.0000

The weights are 0.119, 0.135, 0.144, 0.149, 0.123, 0.095, 0.109 and 0.125 for SS, TDS, COD, BOD, Chlorides, Sulphates, Phosphates and Bio-assay respectively. Now calculate the dominance scores of each industry over other industries, industry pair, for all pollution parameter. All pollution parameter considered as cardinal pollution parameter.

Table 10 : Dominance scores for three chemical industries (water pollutants)

Pair	$\gamma_{ii'}$	Pair	$\gamma_{ii'}$
(1,2)	0.0550	(2,3)	-0.5630
(1,3)	-0.8900	(3,1)	0.8900
(2,1)	-0.0550	(3,2)	0.5630

The standardized dominance scores for each industry pair for all pollution parameter

Table 11 : Standardized dominance scores for three chemical industries (water pollutants)

Pair	$d_{ii'}$	Pair	$d_{ii'}$
(1,2)	0.5309	(2,3)	0.1837
(1,3)	0.0000	(3,1)	1.0000
(2,1)	0.4691	(3,2)	0.8163

The Overall Dominance score of each industry pair for all pollution parameter

Table 12 : Overall dominance scores for three chemical industries (water pollutants)

Pair	$D_{ii'}$	Pair	$D_{ii'}$
(1,2)	0.5304	(2,3)	0.1835
(1,3)	0.0000	(3,1)	0.9990
(2,1)	0.4686	(3,2)	0.8155

The final Appraisal Score of three chemical industries considering water pollutants

Table 13 : Final Appraisal scores for three chemical industries (water pollutants)

	Industry 1	Industry 2	Industry 3
Appraisal Score	1.1317	0.1794	4.4434

Here the appraisal score of three chemical industries are calculated separately for air and water. But finally ranking of three chemical industries are calculated by combining appraisal score of air and water.

Overall score of three chemical industries is calculated and shown in below table.

Table 14 : Overall score of three chemical industries

Criteria	Industry 1	Industry 2	Industry 3	Weight
Air Pollution	1.2611	0.3846	0.6076	0.5
Water Pollution	1.1317	0.1794	4.4434	0.5
Overall Pollution	1.1964	0.2820	2.5255	

Following table shows the final scores of three chemical industries and its ranking.

Table 15 : Final Score for three chemical industries

Final Score (for three chemical industries)	
Industry	EVAMIX Approach
1	1.1964
2	0.2820
3	2.5255

Final ranking of three chemical industries by EVAMIX approach is as shown in following table

Table 16 : Final Ranking for three chemical industries

Industry	Final Ranking
	EVAMIX Approach
1	2
2	3
3	1

Example *2:* Parameters for air and water pollution which are considered to rank the Thermal Power Station Units are SO_X, NO_X, and SPM for air and SS, TDS, BOD, Phosphates, Oil & grease, Total chromium and Total iron for water. Here first score using pollution parameter of air are calculated first and then water. And then final rank has been analyzed.

Score using pollution parameter of air: First decision matrix is forming and it shown below. Here the decision matrix is calculated by taking the average of the three seasonal data as given in table 1.

Table 17 : Decision matrix for three power station units (air)

Industries	Pollutants		
	SO_X	NO_X	SPM
Industry 1	7.36	8.0333	3.6
Industry 2	9.18	137.3333	3.0333
Industry 3	5.0333	7.5	0

Here all the pollution parameters are considered as more contagious pollution parameter. Following table shows normalized decision matrix for three power station units.

Table 18 : Normalized decision matrix for three power station units (air)

Industries	Pollutants		
	SO_X	NO_X	SPM
Industry1	0.4389	0.9961	0.0000
Industry2	0.0000	0.0000	0.1574
Industry3	1.0000	1.0000	1.0000

The weights are 0.329, 0.317 and 0.355 for SO_X, NO_X, and SPM respectively. Now calculate the dominance scores of each industry over other industries, industry pair, for all pollution parameter.

Table 19 : Dominance scores for three thermal power station units (air)

Pair	$\gamma_{ii'}$	Pair	$\gamma_{ii'}$
(1,2)	0.2900	(2,3)	-1.0010
(1,3)	-1.0010	(3,1)	1.0010
(2,1)	-0.2910	(3,2)	1.0010

The standardized dominance scores for each industry

Table 20 : Standardized dominance scores for three thermal power station units (air)

Pair	$d_{ii'}$	Pair	$d_{ii'}$
(1,2)	0.6454	(2,3)	0.0000
(1,3)	0.0000	(3,1)	1.0000
(2,1)	0.3546	(3,2)	1.0000

The overall dominance scores for each industry pair.

Table 21 : Overall dominance scores for three thermal power station units (air)

Pair	$D_{ii'}$	Pair	$D_{ii'}$
(1,2)	0.6460	(2,3)	0.0000
(1,3)	0.0000	(3,1)	1.0010
(2,1)	0.3550	(3,2)	1.0010

Table 22 : The final Appraisal Score of three thermal power station units (air)

	Industry 1	Industry 2	Industry 3
Appraisal Score	1.8197	0.5495	3.0000

Score using pollution parameter of water: First decision matrix is forming and it shown below. Here the decision matrix is calculated by taking the average of the three seasonal data as given in table 1.

Table 23 : Decision matrix for three power station units (water)

Industries	Pollutants						
	SS	TDS	BOD	Phosphates	Oil & Grease	Total Chromium	Total Iron
Industry 1	26.6667	780.6667	15.8	1.6833	0.4667	0.0127	0.0287
Industry 2	47	912.6667	13.3333	1.14333	0	0.0143	0.036
Industry 3	30.1333	838.6667	0	0.746	0	0.0127	0.0313

Here all the pollution parameters are considered as more contagious pollution parameter. Following table shows normalized decision matrix for three power station units.

Table 24 : Normalized decision matrix for three power station units (water)

Industries	Pollutants						
	SS	TDS	BOD	Phosphates	Oil &	Total Chromium	Total Iron
Industry 1	1.0000	1.0000	0.0000	0.0000	0.0000	1.0000	1.0000
Industry 2	0.0000	0.0000	0.1563	0.5806	1.0000	0.0000	0.0000
Industry 3	0.8298	0.5606	1.0000	1.0000	1.0000	1.0000	0.8571

The weights are 0.151, 0.181, 0.209, 0.135, 0.113, 0.134 and 0.140 for SS, TDS, BOD, Phosphates, Oil & grease, Total chromium and Total iron respectively. Now calculate the dominance scores of each industry over other industries, industry pair, for all pollution parameter.

Table 25 : Dominance scores for three thermal power station units (water)

Pair	$\gamma_{ii'}$	Pair	$\gamma_{ii'}$
(1,2)	0.1490	(2,3)	-0.9500
(1,3)	0.0150	(3,1)	-0.0150
(2,1)	-0.1490	(3,2)	0.9500

The standardized dominance scores for each industry pair

Table 26 : Standardized dominance scores for three thermal power station units (water)

Pair	$d_{ii'}$	Pair	$d_{ii'}$
(1,2)	0.5784	(2,3)	0.0000
(1,3)	0.5079	(3,1)	0.4921
(2,1)	0.4216	(3,2)	1.0000

The overall dominance score of each industries pair of all pollution parameter

Table 27 : Overall dominance scores for three thermal power station units (water)

Pair	$D_{ii'}$	Pair	$D_{ii'}$
(1,2)	0.6149	(2,3)	0.0000
(1,3)	0.5399	(3,1)	0.5231
(2,1)	0.4481	(3,2)	1.0630

The final Appraisal Score of three thermal power station units for water pollutants

Table 28 : Final Appraisal scores for three thermal power station units (water)

	Industry 1	Industry 2	Industry 3
Appraisal Score	0.5890	0.7288	0.9689

Table 29 : The final score of three thermal power station units are calculated and shown in following table.

Criteria	Industry 1	Industry 2	Industry 3	Weight
Air Pollution	1.8197	0.5495	3.0000	0.5
Water Pollution	0.5890	0.7288	0.9689	0.5
Overall Pollution	1.2044	0.6392	1.9845	

Following table shows the final scores of three thermal power station units.

Table 30 : Final Score for three power station units

Final Score (for three power station units)	
Industry	EVAMIX Approach
1	1.2044
2	0.6392
3	1.9845

Final ranking of three thermal power station units by EVAMIX approach is as shown in following table based on their pollution potential.

Table 31 : Final Ranking for three power station units

Industry	Final Ranking
	EVAMIX Approach
1	2
2	3
3	1

III. Conclusion

The whole study demonstrates the use of EVAMIX approach for the ranking of the industries based on their Environmental Pollution Potential with the case studies. The EVAMIX approach, used in this study, calculates the appraisal score by comparing each industry over other industry for all qualitative and quantitative pollution parameter.

As the pollution levels in general are on increase, it is opined that the issue of pollution tax should be studied and considered by decision makers of developing countries to control the pollution levels in the environment

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