ENVIRONMENTAL POLLUTION POTENTIAL RANKING OF INDUSTRIES USING OCRA APPROACH

[1]Nisha Soni, [2]Mayuri Prajapati

[1]Research Scholar, [2]Research Scholar,
[1]Department of Civil Engineering, [2]Department of Civil Engineering,
[1]SVNIT, Surat, India, [2]SVNIT, Surat, India.

Abstract : Environmental Pollution Potential Index (EPPI) comprehensively captures various dimensions of pollution without losing important information embedded into it. The aim of the study is to prioritize industries in the order of planning needs for interventions. EPI therefore, forms the basis for comprehensive remedial action plan for the identified severely polluted/critically polluted industries. Operational competitiveness rating (OCRA) is a relative performance measurement approach based on a non-parametric model. The performance ratings obtained by OCRA are not at all sensitive to the numbers of inputs and outputs or the number of industry groups. OCRA as analyzing tool has got some new features compared to the most accepted and used non-parametric evaluation procedure. After calculating the appropriate performance measurements we can analyze the relationship between industries based on pollutants, as well as to analyze the efficiency of industries in the countries.

***IndexTerms* - Environmental Pollution, Multi-criteria Decision Making, OCRA (Operational Competitiveness Rating Analysis) 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 potential-index (EPPI) helps in quantifying the environmental health of the critically polluted industries by synthesizing available information on environmental status by using quantitative criteria.

For this purpose, various methods have been developed and evaluated in the past. However, there still exist enormous challenges in quantifying the environmental characteristics of critically polluted industries.

An innovative method of developing EPPI for relative ranking of industries based on properties of hazardous pollutants emitted. Different decision-making criteria have been incorporated in the development of EPPI.

II. Current Scenario of Pollution

Anthropogenic activities are one of the major sources of environmental pollution. In the recent past, the problem of pollution, and its adverse ecological impacts have been aggravated by an increase in the scale of residential, industrial, and other developmental activities including hydroelectric power plant projects, mining, and so on. This has led to a realization that there is a need to formulate an objective method to quantify the environmental conditions of such polluted industries. Besides, there has been a growing concern about environmental sustainability, which has attracted the concerted efforts of researchers from different disciplines including natural sciences, social sciences, engineering, and the humanities. The ever-increasing world population, coupled with the growing societal demands, have been triggering rapid pace of industrialization, resource extraction, and intensive production. Unfortunately, such swift industrialization and urbanization has caused negative environmental effects, damaging the ecosystem. Resource depletion, greenhouse effect, global warming, acidification, air pollution, water pollution, soil pollution, and their impact on human health are some of the major negative consequences.

III. Methodology

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 identify their problematic dimensions. Accordingly, measures have to be taken to make our process of industrial development and economic growth more sustainable. The biggest hindrance in this task is the lack of tools to identify the problematic areas and the lack of an objective criterion to rank these industries in order of their needs for mitigation measures and, hence, the resources.

This has led to the realization of the need for an objective method so as to analyze the environmental conditions of the identified industries.

Operational Competitiveness rating Analysis (OCRA) is a non- parametric procedure which calculates relative efficiency. At an intuitive level, OCRA computes the efficiency of a decision making unit relative to a set of decision making units by taking into consideration all the relevant input-consuming and output generating activities of the decision making units and assigning ratings to gauge their relative efficiency in these activities.

The OCRA ratings illuminate the operational competitiveness of a particular decision making unit in two aspects: (i) they can indicate the relative efficiency of that unit to the others or (ii) in contrary; they may point its inefficiency. In order to understand performance measurement of any decision making unit, we need to construct a meaningful relationship between the inputs used and the output produced by that unit (Parkan 1991).

OCRA approach: The procedural steps of the current method are described as follows (Ashby et al.2004; Chatterjee and Chakraborty 2012):

Step 1: Compute the preference ratings with respect to the non-beneficial attribute.

In this step, OCRA method is only concerned with the scores that various alternatives receive for the input attribute without considering the scores received for the beneficial attribute. The lower values of non-beneficial or input criteria are more preferable. The arrogate performance of i^{th} alternative with respect to all the input attribute is calculated using the following equation:

$$\bar{I_\iota} = \sum_{j=1}^{n} w_j \frac{\max(x_j^m) - x_i^j}{\min(x_j^m)} \quad (i = 1, 2, \ldots\ldots\ldots, m;\ j = 1, \ldots\ldots, n;\ i \neq m) \qquad (3.1)$$

Where $\bar{I_\iota}$ is the measure of the relative performance of i^{th}alternative and $x_i^j$is the performance score of i^{th} alternative with respect to j^{th} input criterion. If i^{th} alternative is preferred to m^{th} alternative with respect to j^{th} criterion, then $x_i^j < x_j^m$. The term $\frac{\max(x_j^m) - x_i^j}{\min(x_j^m)}$ indicates the difference in performance scores for criterion j, between i^{th} alternative and the alternative whose score for criterion j is the highest among all the alternatives considered. The calibration constant w_j (relative importance of j^{th} criterion) is used to increase or reduce the impact of this difference on the rating $\bar{I_\iota}$ with respect to j^{th} criterion.

Step 2: Calculate the linear preference rating for the input criteria (Chatterjee and Chakraborty 2012):

$$\bar{\bar{I_i}} = \bar{I_\iota} - \min(\bar{I_\iota}) \qquad (3.2)$$

This linear scaling is done to assign a zero rating to the least preferable alternative. $\bar{\bar{I_i}}$represents the aggregate preference rating for i^{th} alternative with respect to the input criteria.

Step 3: Compute the preference ratings with respect to the beneficial criterion (Chatterjee and Chakraborty 2012):

The aggregate performance for i^{th} alternative on all the beneficial or output criteria is measure using the following expression:

$$\bar{O_\iota} = \sum_{h=1}^{H} w_h \frac{x_h^j - \min(x_h^m)}{\min(x_h^m)} \qquad (3.3)$$

Where h=1, 2,.., H indicates the number of beneficial attributes or output attribute and W_h is calibration constant or weight importance of h^{th}output criteria. The higher an alternative's score for an output criterion, the higher is the preference for that alternative. It can be mentioned that $\sum_{j=1}^{n} w_j + \sum_{h=1}^{H} w_h = 1$.

Step 4: Calculate the linear preference rating for the output criteria using the following equation:

$$\bar{\bar{O_\iota}} = \bar{O_\iota} - \min(\bar{O_\iota}) \qquad (3.4)$$

Step 5: Compute the overall preference ratings (Chatterjee and Chakraborty 2012).

The overall preference rating for each alternative is calculated by scaling the sum ($\bar{\bar{I_i}}$+$\bar{\bar{O_\iota}}$) so that the least preferable alternative receives a rating of zero.

The overall preference rating (P_i) is calculated as follows:

$$Pi = (\bar{\bar{I_i}} + \bar{\bar{O_\iota}}) - \min(\bar{\bar{I_i}} + \bar{\bar{O_\iota}}) \qquad (3.5)$$

The alternatives are ranked according to the values of the overall preference rating. The alternative with the highest overall performance rating receives the first rank.

IV. CASE STUDY

The case study relates to the available air and waste water characteristics from three chemical industries, three thermal power station units and five dying & printing industries located in Gujarat state, India. Table 4.1 shows the effluent characteristics of the treated waste water and the stack emissions for three chemical industries monitored for winter (M_1), summer (M_2), and rainy season (M_3).

Table 4.1 Effluent characteristics of wastewater and stack emissions for three chemical industries

Sub Criteria	GPCB limit	Industry A			Industry B			Industry C		
		M_1	M_2	M_3	M_1	M_2	M_3	M_1	M_2	M_3
Air Pollution										
SO_X	100ppm	12.3	13.12	3.4	61.9	80	110	15	25	45
NO_X	50 ppm	21.5	30	36	58	49	55	14	35	36
SPM	150	60	55	80	20	175	60	175	220	159
Cl_2	9mg/Nm^3	4.5	3.66	3.91	0	0	0	0	0	0
HCl	20mg/Nm^3	0	0	0	0	0	0	0	0	0
Water Pollution										
SS	100 mg/l	114	95	65	75	85	50	20	30	40
TDS	2100 mg/l	4500	4225	4775	2175	2640	2591	1110	1200	1235
COD	250 mg/l	75	85	99	88	110	125	89	60	50
BOD	30 mg/l	25	29	31	45	35	32	20	25	18
Chlorides	600 mg/l	275	350.6	500.3	90	125	150	750	100	250
Sulphates	1000 mg/l	1610	1375	1590	0.26	0	1.5	600	550	475
Phosphates	5 mg/l	0	0	0	6	3.45	6.5	0	0	0
Bio-assay	90%	75%	85%	50%	75%	60%	50%	100%	95%	100%

Table 4.2 shows the effluent characteristics of the treated waste water and the stack emissions for three thermal power station units monitored for winter (M_1), summer (M_2), and rainy season (M_3).

Table 4.2 Effluent characteristics of wastewater and stack emissions for three thermal power station units

Sub Criteria	GPCB limit	Industry A			Industry B			Industry C		
		M_1	M_2	M_3	M_1	M_2	M_3	M_1	M_2	M_3
Air Pollution										
SO_X	100ppm	3.61	6.22	12.25	12.2	9.21	6.1	4.8	4.2	6.1
NO_X	50 ppm	7.21	6.4	10.4	140	140	132	7.9	7.4	7.2
SPM	150 mg/Nm^3	0	7	3.8	3.6	3.1	2.4	0	0	0
Water Pollution										
SS	100 mg/l	16	34	30	57	46	38	32.4	30	28
TDS	2100mg/l	790	740	812	1054	844	840	876	804	836
BOD	30 mg/l	15.4	18	14	12	14	14	0	0	0
Phosphates	5 mg/l	2.68	0.97	1.4	1.41	0.98	1.04	0.418	0.7	1.12
Oil &grease	10 mg/l	1.4	0	0	0	0	0	0	0	0
Total chromium	2 mg/l	0.01	0.012	0.012	0.02	0.01	0.01	0.014	0.01	0.012
Total iron	1 mg/l	0.03	0.026	0.028	0.04	0.03	0.03	0.034	0.03	0.032

Table 4.3 shows the effluent characteristics of the treated waste water and the stack emissions for five dying and printing industries monitored for winter (M_1), summer (M_2), and rainy season (M_3).

Table 4.3 Effluent characteristics of wastewater and stack emissions for five dying and printing industries

Sub Criteria	GPCB Limit	Industry A			Industry B			Industry C			Industry D			Industry E		
		M_1	M_2	M_3	M_1	M_2	M_3	M_1	M_2	M_3	M_1	M_2	M_3	M_1	M_2	M_3
Air Pollution																
SO_X	100 ppm	51.48	40.8	41.5	55.05	42.82	43.62	58.2	52.74	55.25	32.51	34.66	70.4	51.48	55.46	47.74
NO_X	50 ppm	6.27	6.5	6.6	2.82	2.14	2.41	6.05	6.08	6.11	5.27	5.34	4.36	6.27	5.98	6.34
SPM	150 mg/Nm^3	149	128.3	132.09	117.3	96.11	101.7	149	134.1	135.9	128.5	135.68	104	149	146.4	150
Water Pollution																
SS	100 mg/l	76	51	42	103	48	60	110	86	120	49	64	49	83	48	64
COD	250 mg/l	225.3	338.5	259.63	290	420	270	375	640	410	249	278.88	249	275	280	255
BOD	30 mg/l	25	35	26	35	54	30	50	79	53	27	33	31	31	26	30
Color	100 co-pt	75	60	65	72	65	45	110	105	90	55	65	55	95	95	80
Amonical Nitrogen	50 mg/l	2.12	1.5	1.78	10.8	10.4	13.51	14.2	8.83	13.9	2.21	0.663	2.07	3.98	11.61	3.62
Oil & grease	10 mg/l	4.2	4.6	1.8	3.2	4.4	1.8	3.4	3	4.2	2	1.4	2	2.4	2.8	2.8
Phenolic Compounds	1 mg/l	0.281	0.36	0.222	0.352	0.318	0.321	0	0	0	0.2	0.165	0.4	0.21	0.205	0.21
Total chromiu	2 mg/l	0.046	0.038	0.065	0.049	0.054	0.099	0.12	0.036	0.118	0.078	0.04	0.09	0.301	0.712	0.128

Data mentioned in above three tables has been adopted here to evaluate the ranking of the industries. Data collected from the different industries are seasonal data. It means the data have been collected for 3 different seasons in a year for each industry. In this paper three case studies have been taken to calculate the ranking of industries. First example is three chemical industries and second example is three thermal power plants unit. The OCRA approach is used here to calculate the ranking of industries, how one industry is better than other industries. In OCRA the ranking of all alternatives is calculated by considering all attributes. To carry out the EPPI of different industries, all pollutants are considered here as attributes and all industries as alternatives. The pollutants emit from the industries are discharged in air and water thus the calculation of all alternatives is divided in two parts. 1) Calculate Overall Preference rating using pollutants (attributes)emit in air 2) Calculate Overall Preference rating using pollutants (attributes)emit in water.

Example 1: In this example the ranking of three different chemical industries is calculated using OCRA approach. The data given in table 4.1 for three chemical different industries is seasonal monitored emission data. For calculation, the average of those seasonal data has been taken and the Environmental Pollution Potential Hazard Index for three chemical industries is carried out as shown below.

Calculate Overall Preference rating using pollutants (attributes) emit in air: Chemical industries emit many pollutants in air. Here only those pollutants are considered which are more harmful or hazardous for living things among all pollutants. The decision matrix is calculated by taking the average of the three seasonal data for three chemical industries and shown in Table 4.4.

Here SO_X, NO_X, SPM and $Cl_2$are considered as attributes (pollutants) to calculate the Overall Preference rating of three alternatives (chemical industries). All attributes must be separated in beneficial and non-beneficial categories. SO_X, NO_X, SPM and Cl_2 are considered as non-beneficial attributes, as those attributes are harmful to living things and also increasing the emission of that increase the air pollution.

Table 4.4 Decision matrix for three chemical industries (air pollutants)

	SO_X	NO_X	SPM	Cl_2
Industry1	9.5900	29.1667	65. .0000	4.0233
Industry2	83.9667	54.0000	85.0000	0.0000
Industry3	28.3333	28.3333	184.6667	0.0000

Denominator in preference rating equation is minimum value from all alternatives for particular attributes. From decision matrix, minimum value for Cl_2 is zero (0) for industry 2 and industry 3, so it is not possible to calculate preference rating. Preference rating is nothing but normalization of decision matrix. Therefore, normalization equation of EVAMIX approach is being used to calculate preference rating.

Weights of all attributes are calculating using fuzzy method after discussing with expert from professional and academician who works in this field from so long. The weights are 0.222, 0.203, 0.221and 0.187 for SO_X, NO_X, SPM and Cl_2respectively. Now calculate preference rating of each alternative over other alternatives for all attributes, shown in table 4.5.

Table 4.5 Preference rating of each alternative over other alternatives for all attributes

	Preference rating	Linear Preference rating	Overall Preference rating
Industry 1	0.6394	0.2683	0.2683
Industry 2	0.3711	0.0000	0.0000
Industry 3	0.5561	0.1850	0.1850

Calculate Overall Preference rating using pollutants (attributes) emit in water: The decision matrix is calculated by taking the average of the three seasonal data for three chemical industries. (Refer Table 4.6).

Table 4.6 Decision matrix for three chemical industries (water pollutants)

	SS	TDS	COD	BOD	Chlorides	Sulphates	Phosphates	Bio-assay
Industry1	91.333	4500	86.3333	28.3333	375.287	1525	0.0000	0.7000
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	0.0000	0.9833

To calculate the overall preference rating of three alternatives (chemical industries),all attributes must be separated in beneficial and non-beneficial categories. SS, TDS, COD, BOD, Chlorides, Sulphates and Phosphatesare considered as non-beneficial attributes, as those attributes are harmful to living things and also increasing the emission of that increase the water pollution. Only Bio-assay is considered as beneficial attribute.

Weights of all attributes are calculating using fuzzy method after discussing with expert from professional and academician who works in this field from so long. The weights are 0.119, 0.135, 0.144, 0.149, 0.123, 0.095, 0.109 and 0.125for SS, TDS, COD, BOD, Chlorides, Sulphates, Phosphates and Bio-assay respectively. Now calculate preference rating of each alternative over other alternatives for all attributes. (Refer Table 4.7).

Table 4.7 Preference rating of each alternative over other alternatives for all attributes.

	Preference rating (beneficial)	Linear Preference rating (beneficial)	Preference rating (non-beneficial)	Linear Preference rating (non-beneficial)	Overall Preference rating
Industry 1	0.0161	0.0161	0.2655	0.0000	0.0000
Industry 2	0.0000	0.0000	0.3420	0.0766	0.0604
Industry 3	0.0726	0.0726	0.7215	0.4560	0.5125

As discussed above, in OCRA approach higher the Overall Preference rating better alternative. So from the results of the Overall Preference rating of three chemical industries, it can be stated that industry 3 is better than industry 1 and industry 2.

Here the overall preference rating of three chemical industries is calculated separately for air and water but finally ranking of three chemical industries are calculated by combining overall preference rating of air and water. Overall score of three chemical industries is calculated and shown in table 4.8.

Table 4.8 Overall score of three chemical industries

Criteria	Industry 1	Industry 2	Industry 3	Weight
Air Pollution	0.2683	0.0000	0.1850	0.5
Water Pollution	0.0000	0.0604	0.5125	0.5
Overall Pollution	0.1341	0.0302	0.3487	

Here equal, i.e. 0.5, weightage has been given to the overall preference rating of air as well as water for chemical industries. Industry 3 has highest overall preference rating compare to industry 1 and industry 2 which means that industry 3 is better among all three industries and also industry 3 is less polluting industry among all the three chemical industries taken for study analysis. Final Score for three chemical industries is shown in table 4.9.

Table 4.9 Final Score (for three chemical industries)

Industry	Fuzzy MCDM	Extended	EVAMIX	OCRA
1	0.4734	0.5	1.1964	0.1341
2	0.5436	0.8663	0.282	0.0302

3	0.443	0.3487	2.5255	0.3487

OCRA and EVAMIX approach is despite in terms of final ranking of alternatives from Fuzzy MCDM approach and Extended TODIM method. In Fuzzy MCDM and Extended TODIM method, higher the overall preference ratings higher the pollution whereas in EVAMIX and OCRA approach higher the rating, lesser the pollution. So finally ranking of three chemical industries are shown in table 4.10.

Table 4.10 Ranking of three chemical industries

Industry	Ranking			
	Fuzzy MCDM Approach	Extended TODIM	EVAMIX Approach	OCRA
1	2	2	2	2
2	3	3	3	3
3	1	1	1	1

From the table, it is noticed that ranking of three chemical industries are same for all methods.

Example 2

Pollutants 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, overall preference rating using attributes of air is calculated and then water. And then final rank has been analyzed.

Calculate Overall Preference rating using pollutants (attributes) emit in air: The data given in table 4.2 for three Thermal Power Station Units is seasonal monitored emission data. The average of those seasonal data has been considered and the Environmental Pollution Potential Hazard Index (EPPI) for three Thermal Power Station Units is carried out as shown below. The decision matrix is calculated by taking the average of the three seasonal data for thermal power station units.(Refer table 4.11).

Here all the attributes are considered as non-beneficial attributes. Table 4.11 shows normalized decision matrix for three power station units.

Table 4.11 Decision matrix for three thermal power station units (air)

	SO_X	NO_X	SPM
Industry 1	7.3600	8.0333	3.6000
Industry 2	9.1800	137.3333	3.0333
Industry 3	5.0333	7.5000	0.0000

Weights of all attributes are calculating using fuzzy method after discussing with expert from professional and academician who works in this field from so long. The weights are 0.329, 0.317and 0.355for SO_X, NO_X, and SPM respectively. Now calculate preference rating of each alternative over other alternatives for all attributes. (Refer table 4.12)

Table 4.12 Calculate preference rating of each alternative over other alternatives

	Preference rating	Linear Preference rating	Overall Preference rating
Industry 1	0.4602	0.4043	0.4043
Industry 2	0.0559	0.0000	0.0000
Industry 3	1.0010	0.9451	0.9451

Score using attributes of water: First decision matrix has been formed and it is shown below. Here the decision matrix is calculated by taking the average of the three seasonal data as given in table 4.2. (Refer table 4.2 and table 4.13).

Table 4.13 Decision matrix for three thermal power station units (water)

	SS	TDS	BOD	Phosphates	Oil & Grease	Total Chromium	Total
Industry 1	26.6667	780.6667	15.8000	1.6833	0.4667	0.0127	0.0287
Industry 2	47.0000	912.6667	13.3333	1.14333	0.0000	0.0143	0.0360
Industry 3	30.1333	838.6667	0.0000	0.7460	0.0000	0.0127	0.0313

Here all the attributes are considered as non-beneficial attributes. Table 4.13 shows normalized decision matrix for three power station units.

Weights of all attributes are calculating using fuzzy method after discussing with expert from professional and academician who works in this field from so long. The weights are 0.151, 0.181, 0.209, 0.135, 0.113, 0.134 and 0.140for SS, TDS, BOD, Phosphates, Oil & grease, Total chromium and Total iron respectively. Now calculate preference rating of each alternative over other alternatives for all attributes. (Refer Table 4.14).

Table 4.14 Preference rating of each alternative over other alternatives

	Preference rating	Linear Preference rating	Overall Preference rating
Industry 1	0.6060	0.3826	0.3826
Industry 2	0.2234	0.0000	0.0000
Industry 3	0.9079	0.6845	0.6845

The final score of three thermal power station units are calculated and shown in table 4.15.

Table 4.15 Final score of three thermal power station units

Criteria	Industry 1	Industry 2	Industry 3	Weight
Air Pollution	0.4043	0.0000	0.9451	0.5
Water Pollution	0.3826	0.0000	0.6845	0.5
Overall Pollution	0.3935	0.0000	0.8148	

Here equal, i.e. 0.5, weightage have been given to the overall preference rating of air as well as water for power station units. From the table, one can noticed that industry 3 has highest overall preference rating compare to industry 1 and industry 2it means that industry 3 is better among all three industries and also that industry 3 is less polluting industry among all the three thermal power station units considered here for study analysis .Final Score for three power station units are shown in table 4.16.

Table 4.16 Final Score (for three power station units)

Final Score (for three power station units)				
Industry	Fuzzy MCDM Approach	Extended TODIM	EVAMIX Approach	OCRA
1	0.1667	0.5148	1.2044	0.3935
2	0.3030	1.0000	0.6392	0.0000
3	0.0910	0.0000	1.9845	0.8148

OCRA and EVAMIX approach is despite in terms of final ranking of alternatives from Fuzzy MCDM approach and Extended TODIM method. In Fuzzy MCDM and Extended TODIM method higher the overall preference ratings higher the pollution whereas in EVAMIX and OCRA higher the rating, lesser the pollution. So finally ranking of three power station units are shown in table 4.17.

Table 4.17 Final ranking of three power station units

Industry	Ranking			
	Fuzzy MCDM Approach	Extended	EVAMIX Approach	OCRA
1	2	2	2	2
2	3	3	3	3
3	1	1	1	1

From the table, it can be stated that ranking of three power station units are same for all methods.

Example 3

Pollutants for air and water pollution which are considered to rank the Dying and Printing Unit are SO_X, NO_X, and SPM for air and SS, COD, BOD, Color, Amonical Nitrogen, Oil and Grease, Phenolic Compounds and Total Chromium for water. First overall preference rating using attributes of air is calculated and then water and lastly final rank has been analyzed.

Calculate Overall Preference rating using pollutants (attributes) emit in air: The data given in table 4.3 for five Dying and Printing Units is seasonal monitored emission data. The average of those seasonal data has been considered and the Environmental Pollution Potential Hazard Index (EPPI) for five Dying and Printing Units has been carried out as shown below. The decision matrix is calculated by taking the average of the three seasonal data for Dying and Printing Units. (Refer Table 4.18).

Table 4.18 Decision matrix for five dying and printing units (air)

	SO_X	NO_X	SPM
Industry 1	44.5933	6.4567	136.4667
Industry 2	47.1633	2.4567	105.0092
Industry 3	55.4000	6.0800	139.4967
Industry 4	45.8400	4.9900	122.8000
Industry 5	51.5600	6.1967	148.4367

Here all the attributes are considered as non-beneficial attributes. Table 4.18 shows normalized decision matrix for three power station units.

Weights of all attributes were computed using fuzzy method after discussing with expert from professional and academician who works in this field from so long. The weights are 0.329, 0.317and 0.355for SO_X, NO_X, and SPM respectively. Now calculate preference rating of each alternative over other alternatives for all attributes. (Refer Table 4.19).

Table 4.19 Preference rating of each alternative over other alternatives

	Preference rating	Linear Preference rating	Overall Preference rating
Industry 1	0.4268	0.3239	0.3239
Industry 2	0.9228	0.8198	0.8198
Industry 3	0.1029	0.0000	0.0000
Industry 4	0.6168	0.5139	0.5139
Industry 5	0.1375	0.0346	0.0346

Score using attributes of water: First decision matrix has been formed and it is shown below. Here the decision matrix is calculated by taking the average of the three seasonal data as given in table 4.3. (Refer table 4.3 and table 4.20).

Table 4.20 Decision matrix for five dying and printing units (water)

	SS	COD	BOD	Color	Amonical Nitrogen	Oil & Grease	Phenolic Compounds	Total Chromium
Industry 1	56.3333	274.4583	28.6667	66.6667	1.8000	3.5333	0.2877	0.0497
Industry 2	70.3333	326.6667	39.6667	60.6667	11.5700	3.1333	0.3303	0.0673
Industry 3	105.3333	475.0000	60.6667	101.6667	12.3100	3.5333	0.0000	0.0913
Industry 4	54.0000	258.9583	30.3333	58.3333	1.6477	1.8000	0.2550	0.0687
Industry 5	65.0000	270.0000	29.0000	90.0000	6.4033	2.6667	0.2083	0.3803

Here all the attributes are considered as non-beneficial attributes. Table 4.20 shows normalized decision matrix for three power station units.

Weights of all attributes have been computed using fuzzy method after discussing with expert from professional and academician who works in this field from so long. The weights are 0.136, 0.183, 0.189, 0.051, 0.117, 0.102, 0.107 and 0.116 for SS, COD, BOD, Colour, Amonical Nitrogen, Oil & grease, Phenolic Compounds and Total chromium respectively. Now calculate preference rating of each alternative over other alternatives for all attributes. (Refer table 4.21).

Table 4.21 Preference rating of each alternative over other alternatives

	Preference rating	Linear Preference rating	Overall Preference rating
Industry 1	0.7750	0.5666	0.5666
Industry 2	0.5321	0.3237	0.3237
Industry 3	0.2084	0.0000	0.0000
Industry 4	0.9019	0.6935	0.6935
Industry 5	0.6366	0.4282	0.4282

The final score of five dying and printing units are calculated and shown in table 4.22.

Table 4.22 Final score of five dying and printing units

Criteria	Industry 1	Industry 2	Industry 3	Industry 4	Industry 5	Weight
Air Pollution	0.3239	0.8198	0.0000	0.5139	0.0346	0.5
Water Pollution	0.5666	0.3237	0.0000	0.6935	0.4282	0.5
Overall Pollution	0.4453	0.5718	0.0000	0.6037	0.2314	

Here equal, i.e. 0.5, weightage have been given to the overall preference rating of air as well as water for dying and printing industries. From the table, it is obvious that industry 4 has highest overall preference rating compare to other industries which means that industry 4 is better among all five dying and printing industries and also that industry 4 is less polluting industry among all the five dying and printing units considered here for study analysis. Final Score for five dying & printing industries are shown in table 4.23.

Table 4.23 Final Score (for five dying and printing industries)

Industry	Fuzzy MCDM Approach	Extended TODIM	EVAMIX Approach	OCRA
A	0.5250	0.5164	0.2358	0.4453
B	0.5068	0.3550	0.5150	0.5718
C	0.5854	0.9968	0.2136	0.0000
D	0.4969	0.1695	0.9507	0.6037
E	0.5717	0.7874	0.2155	0.2314

OCRA and EVAMIX approach is despite in terms of final ranking of alternatives from Fuzzy MCDM approach and Extended TODIM method. In Fuzzy MCDM and Extended TODIM method higher the overall preference ratings higher the pollution whereas in EVAMIX and OCRA higher the rating, lesser the pollution. Finally ranking of five dying and printing units are shown in table 4.24.

Table 4.24 Final ranking of five dying and printing units

Industry	Ranking			
	Fuzzy MCDM	Extended TODIM	EVAMIX Approach	OCRA
A	3	3	3	3
B	2	2	2	2
C	5	5	5	5
D	1	1	1	1
E	4	4	4	4

From the table, it is obvious that ranking of five dying and printing units are same for all methods.

Sensitivity Analysis: In order to check the sensitivity of the model for the given sub criteria, it was proposed to operate the model with discharge norms of GPCB - Gujarat Pollution Control Board for all air pollution attributes and water pollutant attributes considered in this study.

GPCB defines limit for emission of different pollutants in air, water and land to control pollution. Every Industries/Units have to follow these limits for emission of pollutants. GPCB limits in all methods equation is being used to calculate pollution potential for all industries/units for all methods to verify ranking of all industries/units.

While calculating pollution potential index using GPCB limit in OCRA approach, replace maximum value in normalizing by GPCB limit. GPCB limits for different pollutants for different industries are given in table 4.1, 4.2 and 4.3. The ranking was obtained for three chemical industries, three thermal power station units and five dying and printing industries and the same is compared with other approaches. Results obtained for the same are shown in table 4.8, table4. 9, table 4.10; table 4.15, table 4.16, table 4.17 & table 4.22, table 4.23, table 4.24 respectively.

V. Conclusion

The whole study demonstrates the use of OCRA approach for the ranking of the industries based on their Environmental Pollution Potential with the case studies. The OCRA approach, used in this study, calculates the overall preference rating by comparing each alternative over other alternative for all attributes. Following conclusion has been derived from the case studies.

1) When the comparison made among the linguistic variables assignment, by Fuzzy MCDM Extended TODIM method and EVAMIX approach with the OCRA approach, the final ranking of the industries does not change, however, the index value change.
2) When pollution potential index calculated by taking GPCB limit as a reference, ranking of thermal units and chemical industries are remain same. But dying and printing unit's ranking is changed.
3) 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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