WATER QUALITY PARAMETERS ENTROPY ESTIMATION

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ABSTRACT
Water is among the inexhaustible resources but due to the admissible of chemical effluents in large quantities by dumping waste, sewage wastes, and industries discharge into the rivers; contamination of water in some other ways; uncontrollable biological activities; the weather conditions; havoc created by the humans, the quality of water become deteriorating day by day and also from the renewable resources it came to the verge of exhaustible resources. In the present scenario, there is a desideratum to control these particulates which directly or indirectly affect the quality of the water, and also there is a need to stop the overutilization of these precious resources and to deal with the amalgam of the biggest problem of the society i.e., to maintain water quality and quantity with the Multi-Criteria Decision Analysis (MCDA) to provide us a clear view of the parameters which impact the quality. Different parameters like Dissolved Oxygen, pH, Nitrate, and Feacal Coliform of water quality of river Yamuna at different locations are studied using the Entropy method which is used to find the objective weights of the criteria i.e., particulates here. This study majorly reveals the parametric estimations of water quality parameters to find the weightage of the parameters using the Entropy Method of MCDA so that government can take advanced and immediate steps concerning the parameters and also pose strict legal actions against those who are responsible for this major havoc.

KEYWORDS: Entropy Method, Multi-Criteria Analysis, Dissolve Oxygen, Water Quality, Yamuna River

RESUMEN
El agua se encuentra entre los recursos inagotables pero debido a la admisibilidad de efluentes químicos en grandes cantidades por el vertido de desechos, desechos cloacales y descargas industriales a los ríos; contaminación del agua de otras formas; actividades biológicas incontrolables; las condiciones climáticas; Los estragos creados por los humanos, la calidad del agua se deteriora día a día y también los recursos renovables llegan al borde de ser recursos agotables. En el escenario actual, existe el desiderátum de controlar las partículas que, directa o indirectamente, afectan la calidad del agua, así como ,la necesidad de detener la sobreutilización de estos preciados recursos y enfrentar la amalgama del mayor problema de la sociedad, es decir, mantener la calidad y cantidad del agua usando Análisis de Decisión de Criterios Múltiples (MCDA) para brindarnos una visión clara de los parámetros que afectan la calidad. Se estudian diferentes parámetros como el oxígeno disuelto, el pH, el nitrato y los coliformes fecales de la calidad del agua del río Yamuna en diferentes lugares mediante el método de entropía, que se utiliza para encontrar los pesos objetivos de los criterios, es decir, las partículas. Este estudio revela, principalmente, las estimaciones paramétricas de los parámetros de calidad del agua para encontrar el peso de los parámetros utilizando el método de entropía del MCDA para que el gobierno pueda tomar medidas avanzadas e inmediatas con respecto a los parámetros y también plantear acciones legales estrictas contra los responsables de este importante estrago.

PALABRAS CLAVE: método de entropía, análisis multicriterio, oxígeno disuelto, calidad del agua, río Yamuna

1. INTRODUCTION

As we are continuously growing where inventions and modifications in technologies make a big pie of our life. We are so much indulged in these activities that we forget the origin of these technologies and how impact our environment either in a positive way or in a negative way. In the making of these technologies, harmful chemicals are disposed into the water bodies which is the root cause of water pollution. According to the Statista Report, Pollution caused by water kills annually 8.3 million people all over the world, and in India, 2.33m people are affected becoming the third country in terms of pollution. According to the United Nations Environment Programme, one-third of all rivers are affected by pathogens, one-seventh by organic material, and one-tenth due to salinity. The deteriorating level of water quality is due to the innumerous number of factors and parameters involved directly or indirectly and because of the interference of humans and the modernization of the rural and urban area which in turn changes the habit and makes water a scarce resource. Overutilization and Modernization of industries because of which highly intoxicated chemicals are disposed into the water bodies which makes them polluted and not fit for drinking. Even the waste material from the homes is indirectly disposed into the rivers and the overutilization of the resource also plays a vital role in this. As sustainability and the good quality of the water resource is very important for us and for future generations too so it is necessary to find the factors behind the bad quality of this resource and to take major actions as early as possible. Mathematical Optimization paves the way to model the situation in a more practical form so

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that not only from the theoretical point of view, we analyze the problem but also from the modeling view we are trying to find out the optimal solution to this problem to take immediate action for this. But the operation research techniques are difficult to apply in improving the water quality as it contains different objectives with many decision constraints and variables associated with the problem, and also the uncertainty in the case of the resource input briefly explained by Ortega and Berbel (2010). Multi-Criteria Decision Analysis helps us to identify the factors which majorly affect the water quality and quantity and also helps us to identify an optimal alternative for reducing this. It also helps us to measure the risk to our health and the identification of chemicals and their constituents i.e. anions or cations can be analyzed to find out the presence of major ions in the water bodies given by Adimalla, Vasa and Li (2018).

MCDA also plays an important role in the interpretation of opinion experiment results by investigating the attributes involves in causing water pollution which also improves the water quality by taking immediate steps as given by Alothaimeen and Arditi (2019), Cheng and et al. (2019), Ezugwu and et al. (2019). According to Afify (2010), It also helps us in reducing the conflict between drinking water availability and water availability in agriculture.There are many techniques in MCDA like TOPSIS, and Vector Optimization through which we can evaluate the water quality index and identify the quality of water in a different district shown in the literature by Datta and Harikrishna (2005). Even we can assess the effect of the cropping system on the water quality in a particular area and also prioritize our objectives/goals based on the concept given by Ravier and et al. (2015). Weight plays an important role in the MCDA. Basically, there are two types of weights i.e., Objective Weight and Subjective Weight. In the Objective Weights, we already have the data and we can use the data to calculate the weights of the criteria/attributes which contribute more to the objective whereas, in Subjective Weights, we need a decision-maker prior to the calculation of weights. With this, we can take the views of the different decision-makers and combine their views to get optimal data summarised by Yadollahi and et al. (2018) and Zahedi (2017).. This study mainly deals with the MCDA in which we have different conflictive objectives and we want to find the optimal ad compromising solution to the problem. Here water quality parameters using the Entropy method of MCDA are analyzed and prioritized based on the weights we get through this method. The entropy method is used because it takes the help of highly professional decision-makers n evaluate the weights. The entropy method is also known as the weighing method which helps in measuring the deviation in value during the course of decision-making. It can be found that the greater the deviation in the value, the greater the information available from the particular attribute/criteria. In this research, parameters related to water quality like Dissolved Oxygen, pH, Nitrate, and Faecal Coliform are described, and then a case study of river Yamuna is taken to show how these parameters play an important role in causing water pollution and which parameter majorly affect the water quality in Yamuna River at a different location and on which criteria we should be more focus and central and the state government can take steps based on this to improve the quality of the water on the priority basis.

2. DESCRIPTION OF STUDY AREA

The study area taken for undertaking the research is the Yamuna River flowing in different cities. The Yamuna, the longest tributary and the second-largest river in terms of the discharge of water. It is accompanied by various states like Haryana, Uttarakhand, Uttar Pradesh, Delhi, and also indulged with many rivers. Fig. 1. shows the cities and the tributaries which are associated with the Yamuna River. The quality of water at the upper Yamuna i.e., from Yamunotri to Okhla till Wazirabad barrage is of significant-good quality, and below this, between Wazirabad and Okhla, the quality of water is severely poor due to the discharge of chemicals from industries or due to the agricultural discharge or due to the household waste. It is a very small area of the river nearly 2% between this but the same small area contributes 80% of the total polluted river and most of the STPs (Sewage Treatment Plants) installed there are not working so there is a need to identify the factors or particulates that mainly cause water pollution. In this research, our main concern is on the Chemical particulates that are discharged into the rivers and are hazardous for our health, and contaminate water in a more dangerous way. We are trying to find out the weightage of each particulate so that we can come to the conclusion that particulate quantity is severe in the water and has to be controlled immediately.

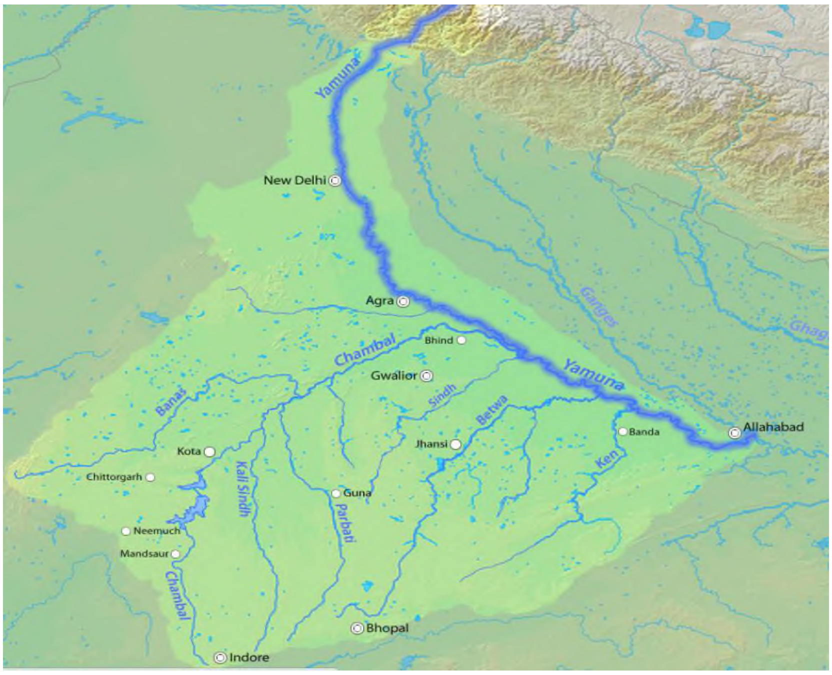

Fig. 1: Yamuna River Map

3.DATA AND METHODOLOGY

Data on the Water quality of River Yamuna of different cities with different stations are taken from the CPCB (Central Pollution Control Board) website. Different parameters of water like Dissolved Oxygen, BDO (Biological Oxygen Demand), pH, Nitrate, and Feacal Coliform are taken into consideration. Those stations whose data are missing are not taken for the study. As both the minimum and maximum levels of particulates are given but here, we are taking the average value of all the particulates. Fig. 2 shows the data taken.

Station Code	LOCATION	STATE	Temperature (° C)		Dissolved Oxygen (mg/ L)		pH		Conductivity (µmho/ Cm)		Bio-Chemical Oxygen Demand (mg/L)		Nitrate (mg/ L)		Faecal Coliform (MPN/ 100 mL)		Total Coliform (MPN/ 100 mL)		Faecal Streptococci (MPN/ 100 mL)	
					> 5.0 mg/L		6.5 - 8.5				< 3.0 mg/L				< 2500 MPN/ 100 mL					
			Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
1554	YAMUNA RIVER, D/S PAONTA SAHIB	HIMACHAL PRADESH	9	24	6.3	9	6.4	8	286	5853	0.4	1.8	0.1	1.4	15	26	39	84	-	-
4439	RIVER YAMUNA U/S RANBAXY	HIMACHAL PRADESH	16	26	6.4	8.4	6.9	7.9	299	728	0.4	0.6	_	0.7	13	25	33	70	-	-
4440	RIVER YAMUNA D/S RANBAXY	HIMACHAL PRADESH	16	29	6.2	8.4	6.8	7.9	369	847	0.4	0.7	0.1	0.8	13	41	34	70	-	-
1117	YAMUNA AT HATHNIKUND, YAMUNANAGAR	HARYANA	20	29	4.8	8.1	7.7	8	128	3430	1.6	3	_	1.7	200	8000	1300	84000	-	-
1496	YAMUNA AT KALANAUR, YAMUNA NAGAR	HARYANA	20	28	4.5	9.2	7.5	8	128	3740	2	2.8	0.1	1.6	1300	40000	2700	426000	-	-
10004	RIVER YAMUNA AT KHOJIPUR PANIPAT	HARYANA	14	26	4.6	11.2	7.3	8.2	243	760	1.3	14	_	1.3	800	140000	3400	426000	-	-
1119	YAMUNA AT SONEPAT	HARYANA	_	_	7.6	9.8	7.1	8.9	226	768	BDL	11	_	1.5	23	94000	23	94000	-	-
1120	YAMUNA AT PALLA, DELHI	DELHI	16	33	6.8	13.2	7.3	8.9	232	618	1.7	8.8	0.6	1.5	20	4100	93	35000	-	-
1121	YAMUNA AT NIZAMUDDIN, DELHI	DELHI	14.7	32.5	BDL	2.4	6.9	7.3	589	1550	7.3	35	0.3	1.2	490000	9200000	490000	24000000	-	-
1375	YAMUNA AT OKHLA BRIDGE (INLET OF AGRA CANAL), DELHI	DELHI	15.4	32	BDL	3.1	7	7.3	610	1240	6.7	28	0.2	1	68000	11000000	68000	17000000	-	-
1812	YAMUNA AT OKHLA AFTER MEETING OF SHAHDARA DRAIN, DELHI	DELHI	18.3	33.2	BDL	3.3	7	7.7	532	1741	8.4	63	0.3	0.8	220000	49000000	490000	49000000	-	-
1497	YAMUNA AT MAZAWALI, U.P	UTTAR PRADESH	_	_	0	5.9	7.1	7.6	486	1910	4.1	47	0.2	1.9	7800	1700000	11000	1100000	-	-
2493	RIVER YAMUNA AT SHAHPUR	UTTAR PRADESH	15	36	2.8	6.4	6.2	7.6	_	_	8	18	_	_	52000	120000	72000	160000	-	-
2495	YAMUNA AT KESIGHAT, VRINDAVAN	UTTAR PRADESH	15	36	4.8	6.1	7.1	7.8	_	_	7.8	11.6	_	_	49000	98000	64000	98000	-	-
1123	YAMUNA AT MATHURA U/S , U.P.	UTTAR PRADESH	_	_	0.6	10.5	7.1	8.1	489	1670	5.8	17	BDL	2.5	1100	35000	1700	79000	-	-
2494	YAMUNA AT VISHRAMGHAT, MATHURA	UTTAR PRADESH	15	36	3.4	6.2	7.1	7.8	_	_	8.6	14	_	_	52000	95000	70000	110000	-	-
1124	YAMUNA AT MATHURA D/S , U.P.	UTTAR PRADESH	_	_	3.5	6.8	7.1	7.8	556	1760	7.1	15	BDL	2	7800	240000	22000	920000	-	-
1125	YAMUNA AT AGRA U/S, U.P.	UTTAR PRADESH	_	_	1.1	7.4	7.1	7.9	604	1790	4.5	15	BDL	4.7	930	17000	1400	28000	-	-
1126	YAMUNA AT D/S OF AGRA, U.P.	UTTAR PRADESH	_	_	0.5	12.6	7	7.9	512	2000	5	21	0.2	3.5	200	79000	2600	140000	-	-
1498	YAMUNA AT BATESWAR, U.P	UTTAR PRADESH	_	_	3	16.9	6.9	8.9	502	1770	4.7	21	0.4	7.2	2	79000	2	350000	-	-
1127	YAMUNA AT ETAWAH, U.P.	UTTAR PRADESH	_	_	4.6	16.2	6.9	8.9	440	1720	4.2	18	0.3	10.1	2	24000	49	92000	-	-

Fig. 2: Data of Yamuna River

4. METHODOLOGY

In this research, we are trying to find out the contribution of each pollutant/particulate so that we can make decisions based on the need of an hour and the most harmful pollutant can be identified using the entropy method in which we are trying to find out the factors that affect the most to the quality of water. Here we are taking the objective weights and creating the decision matrix as the data is available to us and because of the chance of getting a biased result because of the conflict of the decision-maker's views and also mainly due to the past belief, he had in his mind. Basically, entropy gives us the measurement of volatility and the disorderliness of the criteria/attributes. It provides us with the average information that we get from the criteria.

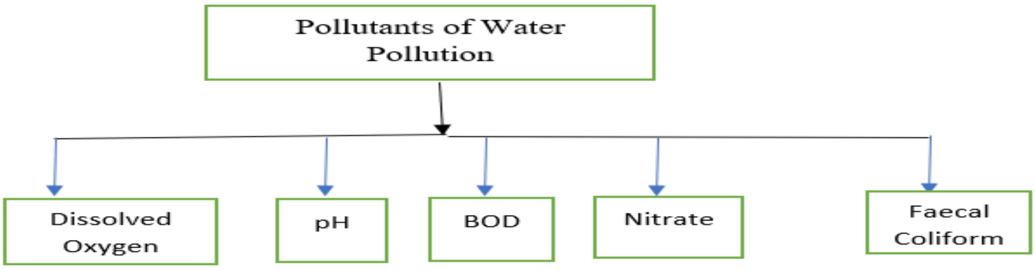

Fig. 3: - Particulates/Criteria of Water

The steps involved in doing the entropy analysis of the Particulates present in water is as follows: -

Step 1: - Collect the data on the different water pollutants which cause water pollution in different rivers of different states/districts/stations. Here we are taking the data on the Yamuna River flowing through all the major stations. Fig. 3 shows the particulates taken for the study.

Step 2: - We are taking 5 pollutants here mainly out of all other water pollutants because these pollutants play a pivotal role in causing water pollution.

Table 1. Matrix Representations

Stations/Pollutants	DO	pH	BOD	Nitrate	FC
S1	Y_{11}	Y_{12}	Y_{13}	Y_{14}	Y_{15}
S2	Y_{21}	Y_{22}	Y_{23}	Y_{24}	Y_{25}
S3	:	:	:	:	:
…..	:	:	:	:	:
Sn	Y_{n1}	Y_{n2}	Y_{n3}	Y_{n4}	Y_{n5}

Here Sn represents the nth station of the Yamuna River at a particular location. Y_{ij} represents the level of the pollutant of type j in the ith station.

Step 3: - Data is not normalized here so we first normalized the data using the weighted sum normalization method. So, the Normalization of the decision matrix can be done by the equation (1): -

Normalization Formula: - $N_{ij} = \frac{Y_{ij}}{\sum_{j=1}^{m} Y_{ij}}$, (1)

where Y_{ij} represents the pollutant level of the ith station of river Yamuna of type j.

Step 4: - Entropy of the criteria now calculated using the equation (2): -

Entropy of the jth type is given by: -

$$E.C._j = -a \sum_{j=1}^{m} N_{ij} \ln N_{ij} \quad (2)$$

Where a = 1/ ln(m)

Where N_{ij} represents the normalized value of the decision matrix.

m represents the number of the stations

Step 5:- Calculation of weights of the criteria using the Entropy discussed above. Weights are given by the following equation (3): -

$$W_j = 1- E.C._j / \sum_{j=1}^{m} (1- E.C._j) \quad (3)$$

Step 6: - After obtaining the weights of each and every criterion, we can find out the individual weightage/contribution of each pollutant and also can find out the pollutant which affects the most to the water and the environment, and also to the health of the people.

5. RESULTS AND CONCLUSİON

Normalization Matrix

Station Code	LOCATION	STATE	DO	pH	BOD	Nitrate	Faecal Coliform
1490	YAMUNA AT U/S DAK PATHER,	UTTARAKHAND	0.0553	0.0412	0.00471	0	3.2923E-06
1553	YAMUNA RIVER, U/S PAONTASAHIB	HIMACHALPRADESH	0.0488	0.0393	0.003425	0.018404908	4.8013E-07
1554	YAMUNA RIVER, D/S PAONTA SAHIB	HIMACHAL PRADESH	0.0475	0.0398	0.00471	0.023006135	5.6244E-07
4439	RIVER YAMUNA U/S RANBAXY	HIMACHALPRADESH	0.046	0.0409	0.002141	0.010736196	5.2128E-07
4440	RIVER YAMUNA D/S RANBAXY	HIMACHAL PRADESH	0.0453	0.0407	0.002355	0.013803681	7.4077E-07
1117	YAMUNA AT HATHNIKUND, YAMUNANAGAR	HARYANA	0.0401	0.0434	0.009848	0.02607362	0.00011249
1496	YAMUNA AT KALANAUR, YAMUNA NAGAR	HARYANA	0.0425	0.0429	0.010276	0.02607362	0.00056655
10004	RIVER YAMUNA AT KHOJIPURPANIPAT	HARYANA	0.0491	0.0429	0.032755	0.01993865	0.00193148
1119	YAMUNA AT SONEPAT	HARYANA	0.054	0.0442	0.047099	0.023006135	0.0012898
1120	YAMUNA AT PALLA, DELHI	DELHI	0.0621	0.0448	0.022479	0.032208589	5.6518E-05
1121	YAMUNA AT NIZAMUDDIN, DELHI	DELHI	0.0149	0.0393	0.090559	0.023006135	0.13292676
1375	YAMUNA AT OKHLA BRIDGE (INLET OF AGRA CANAL),DELHI	DELHI	0.0193	0.0395	0.074288	0.018404908	0.15183007
1812	YAMUNA AT OKHLA AFTER MEETING OF SHAHDARADRAIN, DELHI	DELHI	0.0205	0.0407	0.152858	0.016871166	0.6751966
1497	YAMUNA AT MAZAWALI, U.P	UTTARPRADESH	0.0183	0.0407	0.109398	0.032208589	0.02342748
2493	RIVER YAMUNA AT SHAHPUR	UTTARPRADESH	0.0286	0.0382	0.055663	0	0.00235948
2495	YAMUNA AT KESIGHAT,VRINDAVAN	UTTARPRADESH	0.0339	0.0412	0.041533	0	0.00201654
1123	YAMUNA AT MATHURA U/S ,U.P.	UTTARPRADESH	0.0345	0.042	0.048812	0.076687117	0.00049522
1124	YAMUNA AT MATHURA D/S ,U.P.	UTTARPRADESH	0.032	0.0412	0.047313	0.061349693	0.0033993
1125	YAMUNA AT AGRA U/S, U.P.	UTTARPRADESH	0.0264	0.0415	0.041747	0.144171779	0.00024596
1126	YAMUNA AT D/S OF AGRA,U.P.	UTTARPRADESH	0.0407	0.0412	0.055663	0.056748466	0.00108646
1498	YAMUNA AT BATESWAR, U.P	UTTARPRADESH	0.0618	0.0437	0.05502	0.116564417	0.00108374
1127	YAMUNA AT ETAWAH, U.P.	UTTAR PRADESH	0.0646	0.0437	0.047527	0.159509202	0.00032926
1499	YAMUNA AT JUHIKA B/C WITHCHAMBAL, ETAWAH, U.P	UTTARPRADESH	0.0565	0.0437	0.030186	0.058282209	0.001509
1069	YAMUNA AT ALLAHABAD D/S (BALUA GHAT), U.P	UTTAR PRADESH	0.0575	0.0434	0.009634	0.042944785	0.00013169

Here we are taking 5 pollutants of water that majorly cause water pollution and after converting the data to the average form, we normalized the data. Fig. 4 represents the normalized decision matrix of the data.

After the normalized value, we are calculating the entropy of each of these 5 criteria. The data which has zero values are ignored as the natural logarithm of that value does not exist. Fig. 5. shows the entropy and weight measures.

Station Code	LOCATION	STATE	DO	pH	BOD	Nitrate	Faecal Coliform
1553	YAMUNA RIVEI	HIMACHALPRADESH	-0.1473	-0.1271	-0.01944	-0.073530146	-6.98548E-06
1554	YAMUNA RIVE	HIMACHAL PRADESH	-0.1448	-0.1284	-0.02524	-0.086779011	-8.094E-06
4439	RIVER YAMUN.	HIMACHALPRADESH	-0.1416	-0.1308	-0.01316	-0.048679357	-7.54137E-06
4440	RIVER YAMUN.	HIMACHAL PRADESH	-0.1403	-0.1302	-0.01425	-0.059118681	-1.04564E-05
1117	YAMUNA AT H	HARYANA	-0.1289	-0.1362	-0.0455	-0.09508609	-0.001022808
1496	YAMUNA AT K.	HARYANA	-0.1343	-0.135	-0.04704	-0.09508609	-0.004235501
10004	RIVER YAMUN/	HARYANA	-0.1479	-0.135	-0.11198	-0.078061714	-0.012070749
1119	YAMUNA AT S(	HARYANA	-0.1577	-0.138	-0.14391	-0.086779011	-0.008581391
1120	YAMUNA AT P.	DELHI	-0.1726	-0.1391	-0.08531	-0.11065332	-0.000552799
1121	YAMUNA AT N	DELHI	-0.0627	-0.1271	-0.2175	-0.086779011	-0.268240481
1375	YAMUNA AT OI	DELHI	-0.0761	-0.1277	-0.19313	-0.073530146	-0.286198669
1812	YAMUNA AT OI	DELHI	-0.0797	-0.1302	-0.2871	-0.068870617	-0.265184393
1497	YAMUNA AT N	UTTARPRADESH	-0.0733	-0.1302	-0.24207	-0.11065332	-0.087943152
1123	YAMUNA AT M	UTTARPRADESH	-0.1161	-0.1332	-0.1474	-0.196934168	-0.003768858
1124	YAMUNA AT M	UTTARPRADESH	-0.1101	-0.1314	-0.14435	-0.171237123	-0.019322269
1125	YAMUNA AT A	UTTARPRADESH	-0.0959	-0.132	-0.13259	-0.279224661	-0.00204403
1126	YAMUNA AT D,	UTTARPRADESH	-0.1303	-0.1314	-0.16078	-0.162818537	-0.007414907
1498	YAMUNA AT B.	UTTARPRADESH	-0.172	-0.1368	-0.15956	-0.25053321	-0.007399082
1127	YAMUNA AT E'	UTTAR PRADESH	-0.177	-0.1368	-0.14479	-0.292803652	-0.002640209
1499	YAMUNA AT JU	UTTARPRADESH	-0.1624	-0.1368	-0.10566	-0.165664754	-0.009802928
1069	YAMUNA AT A	UTTAR PRADESH	-0.1641	-0.1362	-0.04473	-0.135183315	-0.001176675
		sum	-2.735	-2.7897	-2.48552	-2.728005935	-0.987631979
		Entropy	0.8983	0.9163	0.816389	0.896037389	0.324396354
		1- Entropy	0.1017	0.0837	0.183611	0.103962611	0.675603646
		Weights	0.0885	0.0729	0.159863	0.090516386	0.588223014

Fig. 5: Entropy and Weight Matrix

From Fig. 5 we can analyze the weights of the different pollutants of the river Yamuna at different places and different stations.

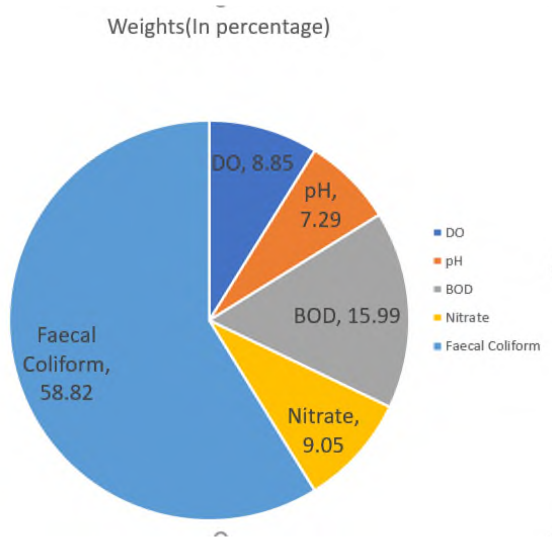

Fig. 6: Weight Distribution

From Fig. 6 we can say that Faecal coliform contributes more to water pollution with a percentage of 58.82% followed by BOD which is 15.99% and Nitrate, 9.05 %. pH and DO contribute less than other pollutants i.e., 8.85 and 7.29% respectively. So, from the results, we can say that we should be more focused on the quantity of Faecal Coliform in the river Yamuna, and Government should take strict actions to control this so that we can get clean and clear water.

6. FUTURE SCOPE

The Multi-Criteria Decision Analysis can be further used to find out the water quality index of the different rivers.

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