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DEFINITION OF A NEW DOMESTIC EFFLUENT QUALITY INDEX USING TOPSIS DECISION MAKING TOOL

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ABSTRACT

Water scarcity is considered as one of the most critical issue in Iran. Managing the domestic effluent for industrial, agricultural and recreational reuses can compensate the water shortage. Effluent Quality Index (EQI), is an efficient tool for rapidly evaluation of the quality achieved by different treatment systems for reuse purposes. The index is developed by a weighted average of eight parameters (TSS, BOD5, COD, NH4, PO4, FECAL COLIFORM, TDS, and PH) which obtained from Delphi method and Fuzzy Topsis decision making tools. Calculation of water quality rating curves (sub-indices) were based on giving a rating scores of 0, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100 corresponding to the 5th , 10th , 20th , 30th, 40th , 50th , 60th, 70th, 80th , 90th, and 99 percentiles respectively to each parameter observations. Then, the thresholds for different reuses and discharges are defined by using environmental limitations and developed EQI. Finally, the effluent quality of South Waste Water Treatment plant of Tehran for summer and autumn is evaluated using the developed EQI.

Keywords: Effluent quality index, reuse, topsis, quality parameters, sub-index.

INTRODUCTION

Water constitutes the most important element of body. Without water there will be no existence of life. Water quality index is a dimensionless number that depends on the combination of chemical, physical, and microbiological parameters. Generally, water quality indices consist of sub-index scores assigned to each parameter by comparing its measurement with a parameter specific rating curve, optionally weighted and combined into the final index (Yagow and Shanholtz, 1996). In order to carry out an accurate analysis of the resources, it is essential to consider and analyze the values assumed by the individual variables which influence quality (Verlicchi *et al*., 2011).Various studies evaluated water quality indices considering different quality parameters. Bhagava (1985) suggested grouping of water quality parameters for potable purpose and evaluated a water quality index for drinking water supplies. Gabriel *et al*. (2000) had combined the surface water quantity and quality objectives to develop water quality routing and water allocation model for Piracizaba River in Brazil. Six management alternatives combining various reservoir policies with differing levels of treatment were suggested. Ahmaid Said *et al*. (2004) defined a new water quality index for Big Lost river water shed in Idhao to assess water quality for general use.

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Babaei *et al*. (2011) developed water quality index for rivers in Iran by using Fuzzy logic to estimate the uncertainties and nonlinear behavior of the system. Sapkal and Valunjkar (2013) estimated water quality index using 25 water quality parameters. This index applied to Purna (Tapi) river basin of Maharashtra (India).Verlicchi *et al*. (2011) assessed a new waste water polishing index for Italian waste water treatment plants using 6 parameters and evaluated the quality index for different treatment sequences. Abhishek and Khambete (2013) developed a multiple regression formula in order to define waste water quality based on CCME method. Different organization set complicated standards and criteria for discharging and reuse of effluent, but understanding all these standards for public is difficult. It is also difficult for the authority to make any decision based on these different parameters. Hence a new approach has been developed and Effluent Quality Index (EQI) has been developed, accordingly. The construction and use of such indices have sparked off widespread debate within the scientific community between supporters and opponents (Ott, 1978; Barbiroli *et al*., 1992).The Index is appropriate tool for Quick comparison of water quality, rapid evaluation of treatment options and Rapid evaluation of the improvement in effluent quality.

The index could be of great help for management and decision makers while planning for water resources. In particular, for comparing effluent quality level achieved by different wastewater treatment sequences (Mudyia, 2012). Legally, discharging or reusing the effluent, must meet all the quality standards. A great number of chemical, physical, and microbiological pollutants should be analyzed, which is a complicated and time consuming job. Additionally, in almost all countries, the tendency is to fix limits of concentrations in water for reuse purposes for many quality parameters without identifying the most appropriate treatments. An effluent quality index which is able to rapidly evaluate the quality of the waste water of municipal treatment plant for reuse purposes, is a very significant tool for decision makers to compare different treatment processes and planning for future. To achieve these goals, in this study an effluent quality index (EQI) is defined and applied in municipal waste water treatment plant in Tehran, Iran. The objective of this study was to define a new method for categorizing effluent regarding the reuse purposes.

MATERIALS AND METHODS

Different treatment process causes various qualities in effluent. In order to achieve a tool for comparing different treatment processes in municipal waste water treatment plants, a new index which is named "Effluent quality index" is defined. Defining a new index for Iranian's effluent of municipal waste water treatment plants includes following steps:

Selection of parameters

Effluent quality depends on several pollutant parameters. Initially, 15 parameter were selected including:
BOD, COD, TSS, TDS, PH, TOTAL P, TOTAL N, NO3, NH3, NO2, T, DO, FECAL COLIFORM, TOTAL COLIFORM, PO4.

Based on Delphi method 100 experts (waste water treatment operators, university professors, waste water consultant companies, waste water managers, PhD students and university professors in waste water treatment) filled the questionnaires and average weighted of each parameter is calculated. Finally, the following parameters are selected: BOD, COD, TSS, PO4, NH4, Fecal coliform, pH, TDS.

Assigning weights

A weight is assigned to each selected parameter based on the achieved result from the Fuzzy Topsis method. The parameter which has the adverse effect on the human health has complicated and expensive treatment process, and more aesthetically unpleasant, is assigned higher weight in questionaries' so that it should make higher EQI. Questionaries' are prepared and panel of experts (waste water plant operators, PhD students and university teachers in waste water treatment) filled the questionaries' based on the criteria. Table 1 indicates a sample of questionaries''. Afterward, the parameters weights are defined Topsis decision making method. The related formula and description about this method can be found in Hwang and Yoon (1981) and Wu and Chen (2007).

Construction of sub-indices for selected parameters

Since these parameters have different ranges and sizes a normalization curve is needed. The third step involved determination of quality function (curve), i.e., sub-index, for each selected parameter. Sub-indices are calculated by converting the value of each selected quality variable into non-dimensional, scaled value through sub-index rating curve. Each variable has its own rating curve on a scale of deteriorating EQI, mostly from 0 to 100 (Kaurish and Younos, 2007; Liou *et al*., 2004).

These rating curves were developed in this study basically from long-term treated waste water analysis data with assistance of waste water quality experts opinions. Calculation of water quality rating (sub-indexes) were based on giving a rating scores of 0, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100 corresponding to the 5^{th}, 10^{th}, 20^{th}, 30^{th}, 40^{th}, 50^{th}, 60^{th}, 70^{th}, 80^{th}, 90^{th}, and 99^{th} percentiles respectively to each parameter observations.

Aggregation and calculation of Effluent quality index (EQI)

Aggregation method is the most important step in calculating WQI. In order to minimize ambiguity and

Table 1. A sample of questionaries' for Topsis method.

Rate of importance	5	4	1	3
Criteria / Parameter	Human health	Cost of treatment	Aesthetically effect	Type of treatment(conventional or advanced treatment)
BOD	2	2	2	2
COD	2	2	2	2
TSS	2	2	2	3
FC (fecal coliform)	5	3	2	5
NH4	4	5	4	5
PO4	4	5	4	5
pH	4	3	3	3
TDS	2	2	3	2

Table 2. The average weighted of Delphi method result.

Quality Parameters	TSS	TDS	pH	COD	AL-KANITY	BOD	Fecal Coliform	NH4	Total P	PO4	TKN	NO3	T
Average weight	3.02	2.97	2.97	2.53	2.40	2.54	4.05	3.28	3.00	3.27	2.12	2.62	2.63

eclipsing, it is necessary to identify an appropriate function for aggregation. (Obaid and Al-Shujairi, 2013). In this study, the multiplicative product method of aggregation is used to overcome problems of eclipsing and ambiguity Overall water quality index is determined by formula given in Eq.1:

$$EQI = \sum_{n=1}^{n=8} W_n I_n \quad (1)$$

Where I_n is the sub-index relating to the parameters COD, BOD, TSS, NH4, PO4, Fc and W_n is the corresponding weight for each parameter.

Case study

The results of this study have applied on the South of Tehran Waste Water Treatment plant, Iran. The process is activated sludge process with nitrogen removal and UV disinfection. The area is about 110 htr and the current usage of the effluent is for irrigation and agriculture. The capacity of this plant is 2600 lit/s and the designed capacity is 3700 lit/s. The population which is covered by this treatment plant is about 4500000.

RESULTS AND DISCUSSION

EQI can be used for comparing different treatment plants performances and investigating the improvement in the quality of treated waste water. As mentioned above, the most significant parameters for discharging the domestic effluent to the surface bodies and for reusing in irrigation and agriculture or recreational activities based on the Delphi method are as fallow: BOD5, COD, TSS, PO4, NH4, fecal coliforms, TDs, pH. The results of Delphi method are presented in table 2.

As it can be seen, fecal coliform, NH4, PO4, TSS, TDS, pH, Bod and COD have more weight respectively. Therefore, these parameters are selected as the most significant parameters.

Topsis method utilized to estimate the rate of importance for each parameter. Topsis method purposed by the Hwang and Yoon (1981). In this method, the selected option should have the minimum distance to the ideal point and maximum distance to the not ideal point.

The related formula and extra description about this method is in the references (Hwang and Yoon, 1981; Wu and Chen, 2007).

Decision makers have filled the questionnaires and assigned a weight 1 to 5 for each parameter considering the adverse effect based on the criteria. In addition each criterion its self, is assigned a weight based on its significance by decision makers. Also, it is supposed that all the decision maker groups have similar weights. Table 3 shows the results achieved by the Topsis method have and assigned the weights to the quality parameters.

Table 3. Assigned weight to the parameters according to the Topsis method.

Parameter	Weighted from Topsis method
BOD	0.0767
COD	0.0767
TSS	0.0885
FC (fecal coliform)	0.1730
NH4	0.1578
PO4	0.1578
pH	0.1344
TDS	0.1352

As it can be seen in table 1, the assigned weights achieved by Topsis method are the expected weights since, fecal coliforms have the most adverse effects on environment and human health and is gotten the highest weight. Therefore, this parameter can deteriorate the EQI and increase the index.

In step 2 the sub -indices should be determined. The associated best-fit formulas to each parameter rating curve were used to calculate aggregated index. Each of eight parameter sub-index (Ii) used to calculate the overall effluent quality index are listed in table 4:

Thus, by substituting the value of sub-indices the EQI formula is calculated by the following relationship:

$$EQI = \sum_{n=1}^{n=8} w_n I_n = 0.076 I_{BOD} + 0.076 I_{COD} + 0.088 I_{TSS} + 0.17 I_{Fc} + 0.157 I_{NH4} + 0.157 I_{PO4} + 0.134 I_{PH} + 0.135\, I_{TDS}$$

Where I is the normalized sub-index of the parameters.

Table 4. Sub-indices formula achieved from rating curves.

Parameter		Sub Index
BOD	If 0≤ BOD≤12	I_{BOD}=-0.3299x^2 + 11.731x - 22.184 R^2 = 0.9975
	If 12<BOD≤107 If BOD>107	I_{BOD}=-12.991ln(x) + 38.244 R^2 = 0.9935 I_{BOD}=100
COD	If COD≤11	I_{COD} =0
	If 11<COD≤53	I_{COD} = -0.0759x^2 + 6.9783x - 67.439 R^2 = 0.9957
	If 53<COD≤165	I_{COD}=8.3501ln(x)+57.746 R^2 = 0.9465
	If 165<COD	I_{COD} =100
TSS	If TSS ≤1	I_{TSS} =0
	If 1< TSS ≤98	I_{TSS}=22.908ln(x)-0.7474 R^2 = 0.9841
	If 98<TSS	I_{TSS} =100
Fecal Coliform	If FC ≤130	I_{FC} =0
	If 130< FC ≤580	I_{FC}= 0.1617x - 19.801 R^2 = 0.9863
	If 580<FC≤3700	I_{FC}=9E-09x^3-6E-05x^2+0.132x+6.6894 R^2 = 0.9892
	If 3700<Fc	I_{FC} =100
NH4	If NH4 ≤0.1	I_{NH4}=0
	If 0.1<NH4 ≤53	I_{NH4}= 16.259ln(x) + 40.013 R^2 = 0.9775
	If 53<NH4	I_{NH4}=100
PO4	If PO4 ≤2.6	I_{PO4}=0
	If 2.6<PO4 ≤5	$I_{PO4=}$-12.083x^3+136.29x^2-465.36x+501.72 R^2 = 0.9938
	If 5<PO4 ≤17	$I_{PO42.=}$6069x + 57.506 R^2 = 0.9815
	If 16<PO4	I_{PO4}=100
TDS	If TDS ≤296	I_{TDS} =0
	If 296<TDS ≤1600	I_{TDS}=1E-07x^3-0.0004x^2+0.4839x-110.99 R^2 = 0.9783
	If 1600<TDS	I_{TDS} =100
pH	If pH≤6	$I_{pH=100}$
	If 6<pH≤9.2	$I_{pH=}$36.394x^2 - 553.95x + 2100.5 R^2 = 0.9814
	If 9.2<pH	I_{pH}=100

Table 5. Reuse and Disposal limitations of treated effluent.

	BOD (Mg/l)	COD (Mg/l)	TSS (Mg/l)	Fecal Coliform	NH4 (Mg/l)	PO4 (Mg/l)	pH	TDS (Mg/l)
Agriculture limitations	100	200	100	400	50	15	6-8.5	1500
Recreational limitations	5	10	30	400	0.02	1	6-9	750
Industrial reuse	30	75	30	200	2	4	6-9	1000
Surface water disposal	30	60	40	400	2.5	6	6.5-8.5	1500
Ground water disposal	30	60	40	400	1	6	5-9	1500

Table 6. Threshold for disposal and reuse of the effluent.

Recreational reuse	26
Industrial reuse	48
Ground water disposal	53
Surface water disposal	56
Agriculture reuse	71
More treatment needed	71<

CONCLUSION

Water quality indices are generally used to assess the level of quality of a particular site. In this study, a new index, the Effluent quality index, has been proposed for three goals: To rapidly compare the various treatment process effluent in different times, To macroscopically represent the quality of the final effluent and To quickly evaluate whether it would be adequate for its final destination (discharge in surface water bodies, recreational or reuse purposes, etc.). Threshold of effluent quality is determined by EQI and legal limitations. Therefore, each waste water sample can be identified with a digit obtained from quality index. So, different samples can be comprised without considering the type of the treatment sequence. This index is defined for South of Tehran waste water treatment plant and can be expanded for all municipal wastewater treatment plants if more data is available for other treatment plants. Thus, the developed index can be a very useful tool for decision makers in managing treated domestic waste water for reuse or disposal purposes. The application of defined EQI for South of Tehran treatment plant is assessed and results indicate that using such indices can help in

Table 7. Concentration of the basic parameters during summer and autumn.

ci	BOD (mg/l)	COD (mg/l)	TSS (mg/l)	PH	nNH4 (mg/l)	PO4 (mg/l)	TDS (mg/l)	FC (CFU/100)
Summer effluent								
Average	7.80	20.40	13.58	6.84	0.15	4.53	660.00	600.00
Min	2.00	12.00	10.00	6.68	0.11	4.00	510.00	250.00
Max	9.00	29.30	18.00	6.90	0.19	5.60	860.00	940.00
Autumn effluent								
Average	7.56	19.11	13.80	7.09	2.56	4.02	615.00	550.00
Min	3.00	9.80	11.00	6.88	0.13	2.44	780.00	770.00
Max	11.00	30.20	24.00	7.80	4.80	4.70	410.00	180.00
Summer influent								
Average	280.37	426.17	141.94	7.50	48.91	5.44	980.00	61000.00
Min	188.00	269.00	108.00	7.26	43.00	4.60	500.00	31000.00
Max	369.00	645.00	180.00	7.56	55.00	6.70	1300.00	89000.00
Autumn influent								
Average	299.08	556.02	152.21	7.73	50.29	5.31	870.00	43000.00
Min	159.00	291.00	82.00	7.52	41.00	4.10	1100.00	75000.00
Max	356.00	891.00	251.00	7.99	62.00	6.80	490.00	22000.00

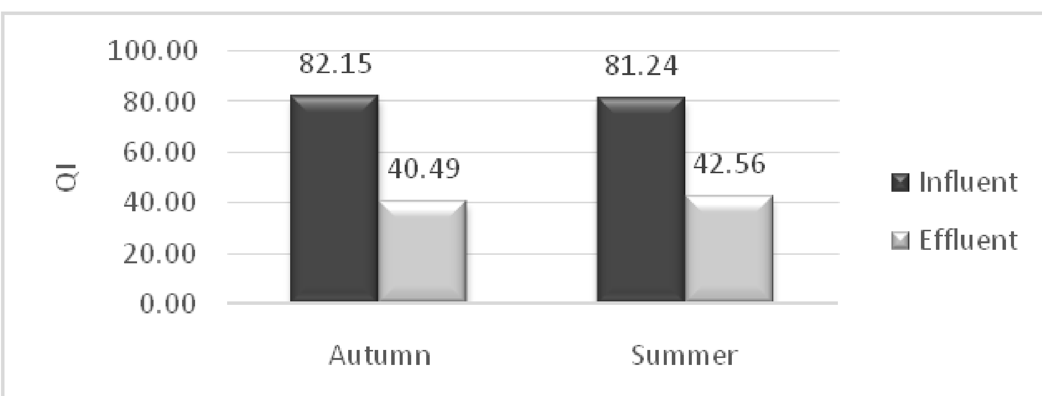

Fig.1. Comparison of EQI between two season and influent and effluent.

decision making for reuse purposes and assessing the improvement in treatment procedure.

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