International Journal of Aquatic Biology (2013) 1(5): 202-208
ISSN: 2322-5270
Journal homepage: www.NPAJournals.com

Original Article

Evaluation of water quality using TOPSIS method in the Zaringol Stream (Golestan Province, Iran)

Zohreh Mazaheri Kohanestani*[1], Rasoul Ghorbani [1], Abdolazim Fazel[2]

[1]Department of Fisheries, Gorgan University of Agricultural Sciences and Natural Resources, P.O. Box 45165-386, Gorgan, Iran.
[2]Department of Fisheries, University of Guilan, Guilan, Iran.

Abstract: In order to evaluate water quality condition, biochemical oxygen demand (BOD), dissolved oxygen (DO), temperature, pH, turbidity, total suspended solid (TSS), phosphate (PO_4^-), nitrate (NO_3^-) and fecal coliform were measured seasonally from 9 sites from November 2009 to August 2010 in Zaringol Stream. Water quality condition was estimated using TOPSIS method. Comparison of TOPSIS values in different sampling stations showed the minimum (0.230) and maximum values (0.604) are in points 1 and 5, respectively. According this result, point 1 had the best water quality condition and point 5 had the lowest quality. Also, Seasonal results of TOPSIS values showed that the maximum value was found in spring. Discharge of effluents from land uses located along the stream specifically, trout farms and starting agricultural activity and production process in spring and summer are most important reasons for decreasing of water quality. TOPSIS estimates values ≤0.5 for almost stations and seasons. It shows Zaringol Stream has an average water quality.

Article history:
Received 8 May 2013
Accepted 21 August 2013
Available online 25 October 2013

Keywords:
Pollution
TOPSIS method
Water quality
Zaringol Stream

Introduction

Rivers play an important role in watersheds for carrying off wastewater and run off from farmland and are the most susceptible water body to pollutants (Yu et al., 2003; Singh et al., 2004; Wang et al., 2007). The constant discharges of wastewater and seasonal surface run-off have a strong effect on the river, water quality, human health and aquatic organisms (Kazi et al., 2009). Water quality zoning is critical to identify preferred potential usages of water resources and source of pollution to optimize water usage and management, especially, in rivers and streams (Simenove et al., 2003; Karimian et al., 2007).

Making decision in the field of water resource management represents a task of high importance and responsibility (Kirilov et al., 2009). Choosing the best option is technically challenging as there is no scientific tools to predict future impacts of alternative management actions (Gao and Hailu, 2011). Since determining of water quality condition is done with numerous different parameters could effect on water quality with different ways as it seems antithetic sometimes, managers use valid index to combine different parameters and calculate a value for taking decision more easily such as NSFWQI, WQI, etc. (Liou et al., 2003; Heernandez-Romero et al., 2004; Simoes et al., 2008). These indexes are comprehensive and common in water quality zoning (Jonnalagadda and Mhere, 2001), though they can throw us in making mistakes when their value are in border ranges of two water quality classes (for example the value belongs to class "bad" but is also so near to the next water quality class "average") .

* Corresponding author: Zohreh Mazaheri Kohanestani
E-mail address: zohremazaheri_65@yahoo.com

Multivariate criteria decision making (MCDM) is one of research fields of management sciences have expanded in different applied researches based on its need recently and It makes it possible to take decision wisely (Saati et al., 2007). TOPSIS is the most famous classical MCDM technique described by Hwang and Yoon (1981) for the first time. In TOPSIS technique, the basic solution method is defining positive and negative ideal (non-ideal) solution (Biorani and Ghofran, 2009). Positive ideal solution includes the best available value of parameters while the non-ideal one is made of the worst available value of parameters. Finally, the best answer has both the shortest distance from the ideal solution and the longest from the non-ideal (Saati et al., 2007). Simplicity, rationality, comprehensibility, good computational efficiency and ability to measure the relative performance for each alternative in a simple mathematical form are some of the advantages of TOPSIS methods (Roszkowska, 2010).

Zaringol Stream with 22 kilometer length is one of the Gorgan-Rud brunches and has important role in water supply of agricultural, aquaculture and domestic usages (Abdoli and Rahmani, 2002). In recent years, great changes have taken in marginal regions lead to severe effect of its water quality though, there is no report on water quality because of limited hydrometric station along the stream. So, the aim of this study is to evaluate water quality using TOPSIS method in Zaringol Stream, the Golestan province.

Materials and Methods

This study was carried out in Zaringol Stream-Golestan Province. Water was sampled from 9 sites along the stream during December 2009 to September 2010, seasonally (Fig. 1). According to Figure 1, after station 1 as the nearest station to the spring and a less polluted station, there are two trout farms located at station 2 and 5 and their actual capacities are 15 and 7 tons, respectively. Other stations are located along the stream where the agriculture is the dominated land use.

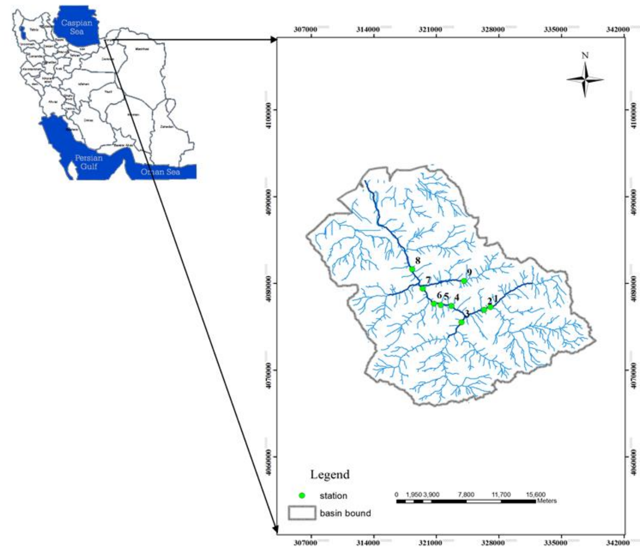

Figure 1. Site of water sampling-Zaringol Stream.

Nine water quality parameters were measured including biological oxygen demand (BOD_5), dissolved oxygen (DO), nitrate (NO^-_3), phosphate (PO^-_4), temperature (ΔT), pH, turbidity, fecal coliform and total suspended solid (TSS) by Water checker u-10 and Spectrophotometer. Decision Matrix (m×n) was made as:

$$\begin{array}{cc} & \begin{array}{cccc} C_1 & C_2 & \dots & C_n \end{array} \\ G = \begin{array}{c} A_1 \\ A_2 \\ \vdots \\ A_m \end{array} & \begin{bmatrix} G_{11} & G_{12} & \dots & G_{1n} \\ G_{21} & G_{22} & \dots & G_{2n} \\ \vdots & \vdots & \dots & \vdots \\ G_{m1} & G_{m2} & \dots & G_{mn} \end{bmatrix} \end{array}$$

A_1, A_2, …, A_m are alternatives; C_1, C_2, …, C_n are evaluation factors; G_{ij} means evaluation rate of A_i related to factor C_j and W is evaluation factor weight were calculated by AHP (eigenvector) method (Gao and Hailu, 2011) (Table 1).

$$W_i = w_1, w_2, \dots, w_n \quad , \quad \sum W_{i=1}$$

Next, data were normalized to remove variation of each factor (Pimerol and Romero, 2000).

$$pij = \frac{Gij}{\sqrt{\sum_{i1}^{m}(Gij)^2}} \quad \forall i = 1,,2, \dots, m$$
$$j = 1,2, \dots, n$$

Table 1. Weight of water quality parameters used in TOPSIS method.

parameter	Unit	Weight
DO	Saturate (%)	0.17
Fecal coli form	Colony/100ml	0.16
pH	---	0.11
BOD_5	ppm	0.11
ΔT	°C	0.1
NO_3	ppm	0.1
PO_4	ppm	0.1
Turbidity	NTU	0.08
T.S.S	ppm	0.07

Table 2. Water quality parameters of different stations - Zaringol Stream.

Parameter/station	1	2	3	4	5	6	7	8	9
Log Turbidity (NTU)	1.46^{a}	2.36^{b}	2.16^{ab}	2.33^{b}	2.49^{b}	2.08^{ab}	2.22^{b}	2.05^{ab}	2.03^{ab}
TSS (ppm)	0.20^{a}	1.06^{c}	0.80^{b}	0.87^{b}	0.95^{b}	0.82^{b}	0.95^{b}	0.84^{b}	0.91^{b}
PO_4 (ppm)	0.36^{ab}	0.88^{b}	0.25^{ab}	0.16^{a}	0.2^{a}	0.12^{a}	0.08^{a}	0.06^{a}	0.11^{a}
NO_3 (ppm)	1.38^{a}	2.18^{a}	1.40^{a}	0.63^{a}	2^{a}	2.08^{a}	2.28^{a}	1.25^{a}	2.35^{a}
pH	8.75^{a}	8.58^{a}	8.75^{a}	8.77^{a}	8.36^{a}	8.56^{a}	8.66^{a}	8.37^{a}	8.30^{a}
T (°C)	14.05^{a}	16.65^{a}	17.18^{a}	20.82^{a}	16.98^{a}	18.68^{a}	19.3^{a}	17.95^{a}	19.35^{a}
DO (%)	66.50^{b}	53.25^{a}	66.25^{b}	66^{b}	54.75^{a}	59.25^{ab}	59.50^{ab}	58.50^{ab}	58.75^{ab}
BOD_5 (ppm)	1.78^{a}	2.75^{bc}	2.38^{ab}	2.23^{ab}	2.83^{bc}	3.30^{c}	3.45^{c}	2.65^{bc}	2.68^{bc}
Fecal coli form×10^5 (counts/100 ml)	1^{a}	2.2^{bc}	2.13^{bc}	1.63^{ab}	2.75^{c}	2.2^{bc}	1.93^{bc}	1.55^{ab}	1.40^{ab}

Data presented as mean.
Similar letter shows no difference between stations.

Table 3. Results of TOPSIS method of different stations-Zaringol Stream.

Station	d_i^+	d_i^-	C_i^*	Rank
1	0.0538	0.0161	0.230	9
2	0.0286	0.0401	0.584	2
3	0.0336	0.0269	0.468	5
4	0.0383	0.306	0.444	6
5	0.0303	0.0461	0.603	1
6	0.0303	0.0335	0.525	4
7	0.0269	0.0371	0.580	3
8	0.0404	0.0221	0.353	8
9	0.414	0.0257	0.383	7

Then weight of evaluation factors was affected by multiplying its vector to decision matrix and provided a normalized weighted decision matrix. Positive ideal (A^+) and non-ideal (A^-) solutions were determined and distance index calculated. "K" and "l" are associated with benefit and cost criteria, respectively (Hwang and Yoon, 1981).

$$A^+ = \{(Max \quad vij \quad j \in J), (Min \quad vij \ j \in J'); \ i = 1,2,K,m\} = \{v_1^+, v_2^+, .., v_n^+\}$$

$$A^- = \{(Min \quad vij \quad j \in J), (Max \quad vij \ j \in J'); \quad i = 1,2,K,m\} = \{v_1^-, v_2^-, .., v_n^-\}$$

$$J = \{K | K = 1,2,K_n\}$$

$$J' = \{l | l = 1,2,K_n\}$$

Table 4. Water quality parameters at different seasons - Zaringol Stream.

Parameter/station	Spring	Summer	Autumn	Winter
Log Turbidity (NTU)	2.24^{b}	2.13^{ab}	1.59^{a}	2.40^{b}
TSS (ppm)	0.6^{a}	1.01^{b}	1.11^{b}	0.57^{a}
PO_4 (ppm)	0.39^{a}	0.33^{a}	0.15^{a}	0.11^{a}
NO_3 (ppm)	1.73^{b}	2.28^{b}	2.51^{b}	0.38^{a}
pH	8.56^{b}	8.33^{a}	8.67^{b}	8.71^{b}
T (◦C)	25.1^{c}	21.44^{b}	10.76^{a}	14.23^{a}
DO (%)	56.78^{a}	63^{a}	60.33^{a}	61.11^{a}
BOD_5 (ppm)	2.93^{b}	2.71^{ab}	2.91^{b}	2.12^{a}
Fecal coli form×105 (counts/100 ml)	2.43^{b}	1.91^{b}	1.60^{a}	1.51^{a}

Data present as mean.
Similar letter shows no difference between stations.

Table 5. Results of TOPSIS method of different seasons - Zaringol Stream.

Seasons	d_i^+	d_i^-	C_i^*	Rank
Spring	0.0238	0.0685	0.742	1
Summer	0.0443	0.0457	0.507	3
Autumn	0.0459	0.0501	0.522	2
Winter	0.0674	0.0210	0.237	4

Finally after calculating the distance from positive ideal solution (di^+), non-ideal solution (di^-) and relative nearest vicinity from ideal answer (Ci^*), values were arranged as an ascending order (Hwang and Yoon, 1981). Maximum value (nearest one to 1) has the highest preference.

$$d_i^+ = \sqrt{\sum_{j=1}^{n}\left(V_j - V_j^+\right)^2} \quad \forall i = 1,2,\dots,m$$

$$d_i^- = \sqrt{\sum_{j=1}^{n}\left(V_j - V_j^-\right)^2} \quad \forall i = 1,2,\dots,m$$

$$C_i^+ = \frac{d_i^-}{(d_i^- + d_i^+)} \quad \forall i = 1,2,\dots,m \quad 0 \le C_i^* \le 1$$

Data checked for normality distribution with the Kolmogorov-Smirnov test. Spatial and temporal variation of water quality parameter were analyzed using one-way ANOVA and Duncan's post-hoc test, assuming a significant level of α=0.05 by SPSS 17 software package.

Results

Data on water quality parameters of different stations are given Table 2. Considering that the point 1 does not expose to the pollution resources, so it was considered as the test station.

According to Table 2, maximum turbidity belongs to stations 2 and 5. Also maximum values of total suspended solid, phosphate were measured in station 2. Dissolved oxygen decreased in station 2 and 5 significantly. Some of water quality parameters had no significant difference between different stations (i.e. pH, temperature and nitrate).

As the aim of calculation was to detect polluted stations in Zaringol Stream, so it should be considered that the nearest value to 1 shows more water pollution (Table 3).

Maximum and minimum relative nearest vicinity from ideal answer (identification polluted points) calculated for station 5 and 1 respectively. In the other hand the most polluted station is 5 and the least one is number 1.

Comparison water quality parameters between different seasons show significant increase in turbidity, temperature, BOD_5 and fecal coli form in spring and NO_3 in summer. pH decreased in summer, too. PO_4 and COD and Salinity did not show significant difference between seasons (Table 4; $P<0.05$).

Relative nearest vicinity from ideal answer in different stations show that winter, summer, autumn and spring rank from high water quality to low, respectively.

Discussion

Results of water quality parameters at different stations of Zaringol Stream showed that the minimum values of total suspended solids, turbidity, biological oxygen demand, fecal coli forms and maximum value of dissolved oxygen were measured in station 1. According to these results, it was the least polluted station, as it is mentioned before. Results of TOPSIS ranking show the minimum value (or best water quality condition) in station 1, so it confirms our claim.

After station 1, a decline could be observed in water quality and some of critical parameters such as biological oxygen demand and fecal coli forms which show water pollution clearly, increased significantly. Similar to the results of water quality parameters, an increasing trend can be observed in the TOPSIS values. Based on the TOPSIS ranking, station 2 had the second grade of water pollution and station 5 was the most polluted station and had the nearest TOPSIS value to 1.

Since stations 2 and 5 are located after trout farms and the concentrations of some ions like phosphate (significantly) and nitrate (not significantly) increased in these stations, it can be infer that entrance of farms effluents had an important effect on water quality condition.

The TOPSIS values showed that station 5 was more polluted than station 2. It is reported that the severity of effect of fish farms effluents on water quality depends on volume and concentration of substances, flow rate of water and time of effluent discharge (Pillay, 2004). Although the actual capacity of first fish farm was more than second ones (located before station 5), station 5 was more polluted because the water loaded a lot of pollution from station 2. Also adding a branch to the main stream flow and bringing a new volume of substances was another probable reason for the highest TOPSIS value in station 5. Comparison of increasing rate of TOPSIS value between station 1 to 2 (0.354) and station 4 to 5 (0.159) confirms that first farm discharge more effluents into the stream than second one.

The increasing trend in TOPSIS values did not resume along the stream and water quality trend to better condition in other stations. Self-purification power of stream improved water quality condition along the stream; though others land uses discharge along the stream prevented it to go back to the first condition again completely.

There are some reports on environmental effect aquaculture (Manoochehri et al., 2010; Uzbilek Kirkagac et al., 2009; Pulatsu et al., 2004; Mmochi et al., 2002) which confirm effect of fish farm effluents on water quality condition. Our results agree with them.

The TOPSIS values show maximum value and the worst condition in spring. Due to climate condition, rain fall decrease in warm season, so because of decreasing of stream flow, concentrations of contaminated components increase and generally stream is in acute condition. In addition to agricultural activity and reproduction period of trout farm start in spring and continue in summer. Therefore water quality of warm seasons may affect more than cold seasons.

Based on Relative nearest vicinity from ideal answer ranged from 0.23 to 0.6 and the theoretical highest value ($C_i^* =1$) we can conclude that Zaringol water quality condition is almost average because most of the TOPSIS values of stations and seasons are ≤0.5.

In summary, the results of our research showed TOPSIS method declared water quality variations clearly as they were expected based on analyzing water quality parameters and can determine polluted stations. Therefore this is an applied simple method and can be used for managers to make decision easily while they are faced to several complicated parameters.

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