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An application of water quality index to reduce the effect of flood on water quality of rivers

Mahmoodreza Nooralinejad*

Department of Water Resources Management, Faculty of Technical and Engineering, Central Tehran Branch, Islamic Azad University, Tehran, Iran

C H R O N I C L E

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A B S T R A C T

The rivers are among the most important resources of water supplying used for drinking consumptions, agriculture, industry, etc. Creation of a regular control plan and monitoring the water quality of these resources are the most important solutions in order to reduce the pollution and promote their qualitative conditions. The changes in climatic such as low levels of rainfall, is one of the factors influencing on the quantitative level of rivers. In addition, weather pollution and reduction in the power of soil resources are very important. This paper presents an investigation to investigate on how to reduce the influences of flood water on the water quality of the rivers based on the model of water quality index. The applied methodology is descriptive-analytical, which uses SPSS software, and t-test and correlation tests are used to analyze the data. The investigation carried out on the influences of the flood water due to raining on the qualitative changes of the water of Cesar River represented that there was a significant relationship between raining, discharge and the parameters of water quality. These relations indicate that the occurrence of raining and increase in the discharge follow the increase in the water quality of the river.

1. Introduction

Water plays essential role for human's life and activities, sufficient water having an appropriate quality is among the most important conditions for accessing to stable development (Srebotnjak et al., 2012). Among the water resources, the rivers are the most important resources of supplying water used for the consumptions of drinking, agriculture, irrigation, industry, etc. (Bordalo et al., 2001). The pollution of the rivers is among the most important issues of the modern world and particularly the developing countries. Iran also encounters this issue with its 4000-year civilization.

Population growth and increase in the human activities in the basin of the rivers, discharge of the household and industrial wastages, agricultural activities, runoff and the latex of the places of disposing the wastages have resulted in reducing the water quality of these resources. Indeed, the human activities have applied undesirable influences on the water body of the rivers along with the natural processes, and they result in increasing the concentration of the pollutants. Therefore, monitoring the water quality

* Corresponding author.
E-mail address: mahmoodnooralinejd@gmail.com (M. Nooralinejad)

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of these resources is of high importance in maintaining them and also in planning and managing the water resources according to the recent droughts and the urban and rural developments (Jähnig et al., 2010). Creation of a regular control plan creates the opportunity to adopt appropriate solutions in the direction of eliminating the pollution of the basin of the rivers (Sanchez, 2007). One of the simplest techniques to determine the qualitative conditions of the water is to use the qualitative indices of water utilized as a tool of decision making for the associated managers and professionals (Ramesh et al., 2010). Among these indices, the water quality index of the national institute of health in America (NSFWQI) has been implemented in many locations of the world which in its calculation, different physical, chemical and biological parameters are measured including dissolved oxygen, PH, all of the solids, the required biochemical oxygen, turbidity, temperature, phosphate, nitrate and excremental coliform. This index is easy to calculate and has been popular index (Tahmasebi et al., 2012). According to what was stated before, this paper presents an investigation to reduce the influences of the floodwater on the quality of the rivers based on the model of the water quality index.

2. Literature review

The prerequisite of the stable development of the water resources is to authorize the secure information about the quantity and quality and the different users' demands. In general, the surface waters are further subjected to the pollution than the underground waters. Usually the surface waters have a high level of coliform, high level of bacteria, turbidity between moderate to high, variable taste, variable smell, solid solutions between less to moderate, variable radioactivity, variable soluble oxygen and variable carbon dioxide. Therefore, the surface waters may not be drunk without treatment, especially bacterial treatment (Rahmani, 2007). In other words, the quality of the surface waters has many changes during the year. The concept of these qualitative changes and fluctuations is that the treatment of the surface waters requires more flexibility than the underground waters. The qualitative indices represent the trend of qualitative changes of water during the time and with respect to the location through simplifying and reducing the raw and initial information, in addition to describe the water quality. In general, the indices of water quality are divided into 5 main groups:

General indices: in this type of indices, the type of usage and water consumption is not considered and disregarding the type of consumption, it proceeds to determine the condition and the qualitative categorization of the water such as the index of water quality of NSF (Filipic, 1995).

Specific consumptions indices: in this type of indices, the categorization of the water quality is carried out based on the type of consumption (public, drinking, agriculture, maintaining the water life and etc.) (Sobhani, 2004).

Statistical indices: in these indices, different statistical methods are used to evaluate and explain the qualitative information of water, and the personal opinions and tastes are less involved in it.

Design indices: these indices are proposed for management decision making in a particular way, and they are principally proposed to help adopting particular decisions or solving specific difficulties.

Biologic indices: the biologic qualitative indices of water generally evaluate the water quality as its influences on the water life (Sheikhestani, 2002).

Indeed, the flood is the over-natural water flow. Such condition is accounted as catastrophe if it endangers the humans' life. In hydrologists' opinion, the size of flood is described in the best way with the maximum flow. The earthquake and flood are proposed as the most important natural disasters in countries like Iran, and what makes calamity out of these disasters is lack of awareness for confronting with its outcomes and prevention from the bad influences of natural events on the essentials of good health, economy and environment. Like other flood-prone areas of the world, in Iran, the intensity of flooding and its resulted damages has increased significantly in the recent decades (Javan et al., 2013).

Hence, management of the flood water is among fundamental measures in water resource planning which is applied for minimizing the potential damages and achieving the stable development of the societies.

In general, the results obtained from the researchers' investigations represent that the rate and the occasions of the appearance of the flood water in each region depends on many factors. The physical characteristics of the basin such as: the shape, the slope, the waterway network and the roughness of the earth along with the hydrological characteristics such as: storage of precipitation and depression and interception losses, evaporation, sudation, penetration and the actions due to human activities are involved in the appearance and intensification of the flood water or reduction and increase in the rate of the damages resulted from it (Fan et al., 2012). Recognition of these factors and classifying them in each region are among the initial principles of controlling the flood and reducing its dangers (Razavi, 2008). In this way, in controlling and struggling with the flood water, recognition of the factors influencing on them has a very high importance. In other words, before any planning for controlling the flood, the behavior of its processes should be recognized.

The factors influencing on the occurrence or intensification of the danger of the flood are as below:

Slope factor: whatever the total slope of the basin surface increases, the time required for penetration of water into the soil is reduced and in other words, with increase in the basin slope, the concentration time reduces.

The factor of the shape of the basin: the shape of the basin influences on the hydrologic characteristics of the basin (e.g. the hydrograph shape). A long narrow basin having a high bifurcation ratio creates a low but constant peak, while the round basins having a low bifurcation ratio would create a sharp hydrograph (Carbajal-Hernández et al., 2012).

Drainage density factor: the value of drainage density is an important index in determining the intensity of the flood waters, the level of the sediment load, the water balance in the whole basin and generally, the quality of the activity of the surface runoff processes (Zahedi & Bayati khatibi, 2008).

Rock type factor: the type of rock and soil cover influences on the capacity of penetration. Penetrable soil or rock provides the conditions of penetration of water into the earth and it delays its discharge into the main water way. This is why the surface runoff reduces. The basins which have relatively impermeable bedrock or soil create a high volume of surface runoff (Garde, 2006).

Vegetation factor: the studies of different researchers represented that the level of water and sediment load, peaks of floodwater and the time of their occurrence, and the maximum rate of flow transfer are extremely influenced by the nature and the development of the vegetation (Garde, 2006).

3. Methodology

The considered study domain is located in a part of Dez basin, in Iran, which its main drainer is constituted by the Cesar River. This river places an area equal to 9434 km² in itself. Its major part is located in the mountainous regions and another part of it includes the plains of Khorramabad, Borujerd, Dorud, Azna and Aligudarz. Cesar River has abundant permanent water. According to the statistics adapted by the regional water authority of the province, 12 stationaries of Hydrometry in the Cesar basin are considered as an independent study limit after entrance of the Sabzeh River into it, and the statistical data related to these 12 sub-basin of Cesar are analyzed.

According to the influences of raining on the changes of the water of the rivers including quantitative and qualitative, in this investigation, it is discussed on the relation and the influences of the floodwater due to raining on the parameters of the water quality of the research domain of Cesar daily. In order to analyze the data, the determined stationaries were sampled daily, and the parameters of the soluble oxygen, fecal coliform, difference in the temperature, biochemical required oxygen, nitrate, turbidity, all phosphates and all soluble solids were measured, and then from the quality index curve of each parameter, its qualitative value was calculated. In order to analyze the information, the statistical software of SPSS is used. In order to compare different stationaries during the sampling from the river, step-by-step regression test, analysis of variance, t test and correlation test were applied.

3.1 Calculation of water quality of index

In calculating the index of NSFWQI, according to the Eq. (1), two factors of the parameter weight and quality of parameter are involved, and in this study, the value of index is obtained for each stationary using the online software of NSFWQI calculator. In this way, by placing the value of each parameter in the mentioned software, the value of index is calculated for each parameter and finally, the index is determined for each considered stationary or month through obtaining the average of the values. This index has a value between 0 and 100 which rates the water quality to excellent (90-100), good (70-90), moderate (50-70), bad (25-50) and very bad (0-25) situations based on Table 1 (Jähnig, 2010). The parameters of temperature, soluble oxygen and in-site PH are measured. The level of soluble oxygen is calculated with the DO-meter device- Winlab model, and PH and temperature are also calculated using the PH-meter- Multi 340 i model which are all portable. The turbidity of the samples is also read in laboratory using the turbidity-meter device- Hach model 2100N made in U.S.A, and the parameters of TS, phosphate, Nitrate, BOD and fecal coliform are also measured based on the methods available in the standard book of method, and in order to analyze the information and data and all required calculations, the spread solution software of Excel and SPSS statistical software are used.

$$\text{NSFWQI}:\sum_{i=1}^{n} W_i Q_i, \tag{1}$$

Table 1

The guide of the water quality index

The index limit	Water quality	Classification of the type of water resource usage
90-100	Excellent	Having natural state, it has no need to be treated if it is used to provide the drinking water, it is appropriate for training the fishery and water-resistant species.
70-90	Good	If it is used to provide the required drinking water, it requires conventional treatment. Appropriate for fish farming and water sensitive kinds, appropriate for recreative purposes like swimming
50-70	Moderate	If it is used to provide the drinking water, it requires the advanced treatment, appropriate for fishery and water-resistant types, appropriate for the domestic animals as the drinking water
25-50	Bad	Appropriate for irrigating the agricultural lands
0-25	Very bad	It is not appropriate for any of the mentioned usages, and it has only the ability of supporting a limited number of the aquatic animals

4. Results

In this study, the investigations have been carried out on the influences of raining on the quantitative and qualitative changes of the water in Cesar River represented and we have to find out whether or not there is a significant relation between the raining, the discharge and other parameters of the water quality. Out of each 12 stations, during the time of 6 months, two samples are extracted and the value of BOD, DO and fecal coliform and other physicochemical parameters were measured. The assessed parameters include dissolved oxygen, fecal coliform, PH, biochemical required oxygen, difference in the temperature, phosphate, nitrate, turbidity, and all dissolved solids. The level of the dissolved oxygen is converted to the percentage of saturation of the dissolved oxygen based on the temperature of the water in the place of sampling, and then, its quality index was determined by setting each factor in the NSF-WQI software, and the water quality index was determined through setting the quality index of the factors in the same software. Eq. (2) states calculation of percentage of saturated DO at the temperature vof sampling as follows,

$$\text{Percentage of saturated DO} = \frac{\text{Measured DO}}{\text{Maximum saturated DO in that temperature}} \times 100. \tag{2}$$

Calculation of water quality index

Factor	Weight	Quality Index
Dissolved oxygen	0.17	
Fecal coliform	0.16	
pH	0.11	
Biochemical oxygen demand	0.11	
Temperature change Go to This Site to Get Index value	0.10	
Total phosphate	0.10	
Nitrates	0.10	
Turbidity	0.08	
Total solids	0.07	

Calculate

Based on the [ ] Factors entered

The water quality index is [ ]

Fig. 1. NSF software for determining the water quality index

Using the results obtained from the tests carried out on the samples of raw water and determination of the seasonal average, the qualitative value of each one of the parameters were calculated.

Table 2
The seasonal average of the WQI parameters measured in the stationaries of the Cesar River

Factor	Measurement unit	Seasonal average			
		Spring	Summer	Fall	Winter
Percentage of the saturated soluble oxygen	%	99.92	67.84	34.89	70.91
Fecal coliform	MPN Per100M	185583	28000	31916	25083
PH	-	925.7	98.7	98.7	90.7
Biochemical required oxygen	Mg.l	8.3	79.3	3.2	20.3
Changes in temperature	oC	3.0	3.0	3.0	3.0
Total phosphate	Mg.l	069.0	036.0	068.0	092.0
Nitrate	Mg.l	98.3	87.4	07.5	02.6
Turbidity	NTU	25.473	83.59	67.42	42.51
All solids	Mg.l	17.775	8.788	7.998	934

Table 3
Mean of quality values of measured WQI parameters of Cesar river stations

factor	weight	Seasonal quality value			
		spring	summer	autumn	winter
Percent of dissolved oxygen	0.17	97	91	94	96
Fecal coliform	0.16	2	7	7	8
PH	0.11	86	85	85	87
Biochemical needed oxygen	0.11	62	62	74	67
Temperature change	0.10	92	92	92	92
Total phosphate	0.10	97	99	97	96
Nitrate	0.10	70	66	65	60
Turbidity	0.08	5	33	43	38
Total solids	0.07	20	20	20	20

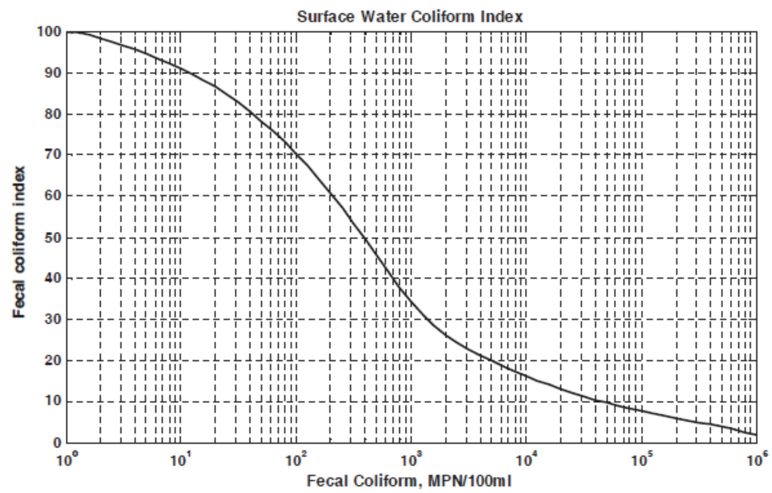

Fig. 2. Fecal coliform (The value of equivalent index is considered 1 for fecal coliform more than 10 MPN/100 ml)

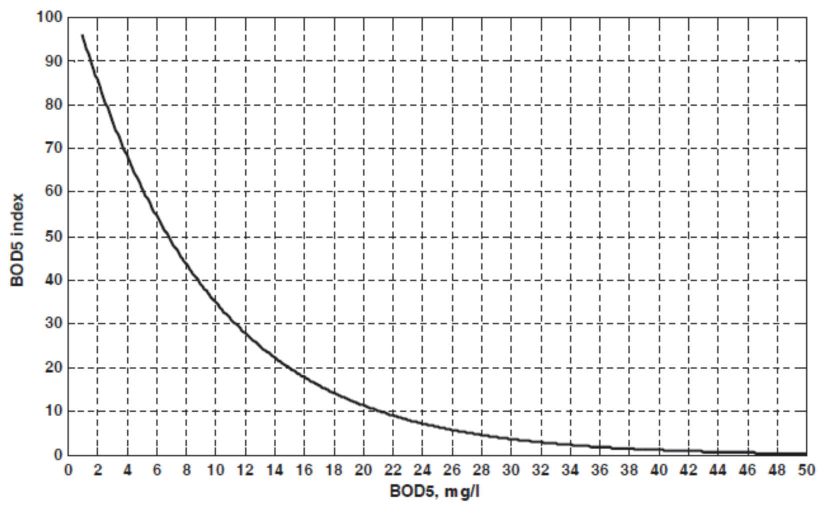

Fig. 3. BOD5 (The value of equivalent index is considered 1 for BOD5 more than 50)

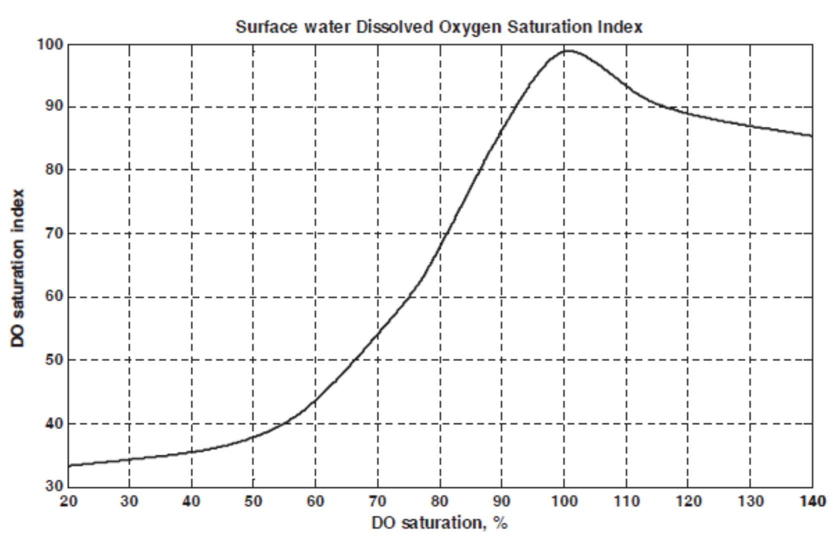

Fig. 4. Dissolved oxygen (the value of the equivalent index is considered 80 for the dissolved oxygen more than 140% of saturation)

The investigation shows that during this study the index of monthly quality of river water in this interval was variable within range of 57-70 and is placed in intermediate group. The index of water quality gradually decreases from the first station until the last one, and the station index in downstream or the annual index of 62.5 had the worst situation and value of the upstream station with the annual index of 65.25 had the best situation. In fact in the upstream station the index had better quality range and in the downstream stations the quality of river water was low and for the last station the lowest value of quality index was registered. To decrease of the effects of flood on the river water the following models can be used:

a) Modifying of the river bed (widening of river bed, deepening by dredging, removing plants of rivers, leveling the surface of river, modifying river path for shortening the river length).
b) Creating flood control dikes (creating walls around rivers, transverse canal and obstacles on the way of flood and divergence of runoffs into other areas, creating flood walls in valleys for prevention from collection of water.)
c) Construction of dams and solid dyke (which being used in power generation and irrigation)
d) Protection from river bed (in high areas using of building materials)
e) Biological protection (planting tree beside rivers and creating vegetation and jungles for decreasing speed of rain drops, creating concrete and stone obstacles in the river bed and floods

5. Conclusion

Flood occurrence and draught in all over the world and our country during recent years has clarified the role and importance of water, and the human society has found that in spite of great technological advances in the field of different technologies we are still unable to confront with natural phenomenon like flood and draught and there is a need for study about suitable strategies. There is a wide range of studies about factors influencing flood damages, but ignorance of hydraulic factors of water flow in the main river streams causes lack of suitable analysis of river conditions during flood. Conduction of a hydraulic model including speed and depth of flow for the main stream of river and considering of river edge lands, which take into account of both the damaging changes of flood and underlying specifications of river, is a perfect measure for analysis of flow in the lands affected by flood. Flood in Iran, because of geologist features and environmental damages, normally creates significant amount of mud. So, most of floods in Iran enforce damages which necessitate prediction of floods and ways of encountering.

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References

Bordalo, A. A., Nilsumranchit, W., & Chalermwat, K. (2001). Water quality and uses of the Bangpakong River (Eastern Thailand). *Water Research*,*35*(15), 3635-3642.

Carbajal-Hernández, J. J., Sánchez-Fernández, L. P., Carrasco-Ochoa, J. A., & Martínez-Trinidad, J. F. (2012). Immediate water quality assessment in shrimp culture using fuzzy inference systems. *Expert Systems with Applications*, *39*(12), 10571-10582.

Fan, X., Cui, B., & Zhang, Z. (2012). Spatial variations of river water quality in Pearl River Delta, China. *Frontiers of Earth Science*, *6*(3), 291-296.

Filipic, M. (1995). Mutagenicity and toxicity of water extracts from the Sora river area. *Mutation Research/Genetic Toxicology*, *342*(1), 1-8.

Garde, R. J., (2006). *River Morphology*. Published by New Age International (P) Ltd., publishers, New York.

Jähnig, S. C. (2010). River water quality assessment in selected Yangtze tributaries: Background and method development. *Journal of Earth Science*,*21*(6), 876-881.

Javan, P., Purtabari, M., & Mirzaei, M., (2013). Zoning of flood risk by flow energy and geographical information system, *Sewage and Water Magazine, 3*, 101.

Najmaei, M., (1990). *Engineering hydrology*, 2nd edition, Iran University of Science and Technology, Tehran.

Rahmani, A, (2007). Determination the quality of water from flowing rivers of hamedan falt in spring base on Wilcox assortment method. Journals collection of tenth Environmental Health national congress. Oc-Nov, 30-1, Hamadan, Iran. (Persian).

Ramesh, S., Sukumaran, N., Murugesan, A. G., & Rajan, M. P. (2010). An innovative approach of drinking water quality index—A case study from Southern Tamil Nadu, India. *Ecological Indicators*, *10*(4), 857-868.

Razavi, A. (2008). *Principles of determination of water resources boundaries*. 1st ed., Water and Electricity Industry University press, Tehran.

Sánchez, E., Colmenarejo, M. F., Vicente, J., Rubio, A., García, M. G., Travieso, L., & Borja, R. (2007). Use of the water quality index and dissolved oxygen deficit as simple indicators of watersheds pollution. *Ecological Indicators*, *7*(2), 315-328.

Sheikhestani N. (2002). Surface water quality indices description and application in qualitative vulnerability assessment and zoning Rivers. (Thesis). Civil Department of Science and Industry University. (Persian)

Sobhani, N. (2004). Study of water quality indices methods and applications in Karun water quality zoning. (thesis) Environmental department of Science and industry University, Iran. (Persian).

Srebotnjak, T., Carr, G., de Sherbinin, A., & Rickwood, C. (2012). A global Water Quality Index and hot-deck imputation of missing data. *Ecological Indicators*, *17*, 108-119.

Tahmasebi, S., Afkhami, M., & Takdastan, A. (2011). Study of Chemical, Physical and Microbial Quality of Gargar River, sw, Iran, Using NSF Water Quality Index. *Iranian Journal of Health & Environment, 4*, 55-64(in Persian).

Zahedi, M., & Bayati khatibi, M., (2008). Hydrology, first edition, SAMT press, Tehran.

Zhang, R., Qian, X., Li, H., Yuan, X., & Ye, R. (2012). Selection of optimal river water quality improvement programs using QUAL2K: A case study of Taihu Lake Basin, China. *Science of the Total Environment*, *431*, 278-285.