ÖHÜ Müh. Bilim. Derg. / OHU J. Eng. Sci.

ISSN: 2564-6605
doi: 10.28948/ngumuh.444731
Ömer Halisdemir Üniversitesi Mühendislik Bilimleri Dergisi, Cilt 7, Sayı 2, (2018), 694-702
Omer Halisdemir University Journal of Engineering Sciences, Volume 7, Issue 2, (2018), 694-702

Araştırma / Research

WATER QUALITY INDEX FOR MEASURING DRINKING WATER QUALITY OF BODRUM PENINSULA-TURKEY

Cengiz KOÇ[1] (ORCID: 0000-0001-7310-073X)[*]

[1] Şehir ve Bölge Planlama Bölümü, Mimarlık Fakültesi, Muğla Sıtkı Koçman Üniversitesi, Muğla, Türkiye

Geliş / Received: *17.11.2017*
Kabul / Accepted: *28.03.2018*

ABSTRACT

Bodrum peninsula is an important tourism center of Turkey. This study is conducted to assess the quality of blended raw waters provided from Çamköy groundwater wells, Mumcular and Geyik dams in terms of Water Quality Index (WQI) with analysis of 22 physicochemical parameters. WQI is regarded as the most effective method of measuring the water quality. The WQI values for the study were calculated as 84.92 and 91.11, respectively. The WQI scores were found 'very poor' for drinking water sources of Bodrum peninsula. The parameters such as Turbidity, Dissolved Oxygen, Biochemical Oxygen Demand, Chemical Oxygen Demand, and Total Hardness were found high above the permissible limit values. The higher values of parameters increase the calculated WQI values. The existing water sources in the Bodrum peninsula need to be treated before used as drinking water. Therefore, the blended raw waters should be treated with the processes include in aeration, coagulation, flocculation, precipitation, filtering and disinfection.

Keywords: Physicochemical parameters, Water Quality Index, drinking water quality, Bodrum Peninsula, Turkey

TÜRKİYE'DE BODRUM YARIMADASI İÇME SUYU KALİTESİNİ ÖLÇMEDE SU KALİTE İNDEKSİ

ÖZ

Bodrum yarımadası Türkiye'nin önemli turizm merkezlerinden birisidir. Bu çalışma, 22 adet fiziksel ve kimyasal parametrenin analiziyle Su Kalite İndeksi açısından Mumcular ve Geyik barajları ile Çamköy yeraltısuyu kuyularından sağlanan harmanlanmış ham suların kalitesini değerlendirmek amacıyla yürütülmüştür. Su Kalite İndeks yöntemi, su kalitesini ölçmenin en etkili yöntemi olarak kabul edilir. Çalışma için Su Kalite İndeks değerleri 84.92 ve 91.11 olarak hesaplanmıştır. Bodrum yarımadasının içme suyu kaynaklarının Su Kalite İndeks puanı "çok kötü" olarak bulunmuştur. Biyokimyasal Oksijen İhtiyacı, Kimyasal Oksijen İhtiyacı, Bulanıklık, Çözünmüş Oksijen ve Toplam Sertlik gibi parametreler izin verilen sınır değerlerin üzerindedir. Parametrelerin yüksek değerleri, hesaplanan Su Kalite İndeks değerlerini artırmaktadır. Bodrum yarımadasındaki mevcut su kaynaklarının içme suyu olarak kullanılmadan önce arıtılması gerekmektedir. Bu nedenle, harmanlanmış ham sular havalandırma, koagülasyon, flokülasyon, çökeltme, filtreleme ve dezenfeksiyonu içeren işlemler ile arıtılmalıdır.

Anahtar Kelimeler: fizikokimyasal parametreler, Su Kalite İndeksi, içme suyu kalitesi, Bodrum Yarımadası, Türkiye

1. INTRODUCTION

[*] Corresponding author / Sorumlu yazar. Tel.: +90 252 2113102; e-mail / e-posta: cengizko9@gmail.com

Providing sufficient amount of water is very important for local settlements such as provinces, cities, towns, and its water quality is of great importance [1]. Water used as drinking water must not contain any harmful microbiological and chemical substances and should meet the water quality standards. Thereof, the concept of drinkable water is very important for all societies in past and today.

Water quality is used to characterize the condition, including the chemical, physical and biological properties of the water, generally according to suitability for a particular purpose [2, 3, 4].Changes in physical and chemical properties of water quality are affected by anthropogenic factors [5, 6, 7], the combined interactive natural processes such as hydrological conditions, climate and topography [8, 6, 9], precipitation and flow inputs [10, 11, 5, 9], size of basin area [8, 9], tectonic structure [8, 6] and edaphic factors [6], erosion events, weathering of crustal materials and bedrock geology [11], combination with environmental influences [8, 9].

It is very difficult to assess the water quality in large samples that each parameter has a different concentration [12]. In such cases, Water Quality Index (WQI) is a very utility and effective method used for determining the suitability of water quality for various purposes. Furthermore, it is a very handy tool for giving the information on the water quality [13, 14]. WQI helps to understand the overall status of water quality for the examined water source. For this reason, the method has been applied the worldwide for assessing the quality of surface and groundwater since the last few decades [15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, and 26]. The aim of WQI is to convert the complex water quality data into clear and useful information that can be reported on the status of water resource by a layman [27, 28]. Factors to be taken into the WQI model may vary according to the planned water uses and local preferences. WQI was developed to integrate the water quality variables used for various purposes [29, 30, 31]. The researcher suggested the first WQI method takes account the weighting of some water quality variables, since that time, the formulation and use of indices for WQI have been vigorously defended by agencies and institutes, responsible for controlling the water supply and water pollution. Canadian Council of Ministers of the Environment's WQI, US National Sanitation Foundation's WQI, British Columbia WQI, Oregon WQI, and Florida Stream WQI have been used for assessing the water quality by various institutes and agencies [32, 33, 34]. This method is also used by the countries such as Brazil, Argentina, USA, Iran, Malawi and Spain [35].

Water quality monitoring studies have a priority to be determined of existing conditions and long-term trends in effective management of water. The unsafe water supply has an important effect on the emergence of water transmitted diseases. The abundance of organic compounds, radionuclide's, toxic chemicals, nitrites and nitrates in the water can cause harmful effects on human health [36]. For this reason, the quality of the water to be used for drinking water must be regularly monitored and assessed.

In order to ensure safe drinking water supply to the Bodrum peninsula with acceptable quality and quantity, it is very important to understand of water quality of the peninsula from the source to the user and identify factors affected it. The purpose of this study is to assess the quality of blended raw waters provided from the groundwater wells of Çamköy, Mumcular and Geyik dams in terms of WQI by analysis of 22 physical and chemical parameters and also to suggest the treatment processes which are required in order to achieve standards for high quality drinking water.

2. MATERIAL AND METHODS

2.1. Material

Bodrum peninsula has the geographical coordinates of 37^o 2' 18" at North Latitude and 27^o 25' 45" at East Longitude. Güllük Bay is found at the north of the peninsula, Gökova Bay at the south and Aegean Sea is located at its West. Bodrum Peninsula has 680 km^2 of area and the shore length is 174 km (Figure 1). As a geological formation, it contains old Paleozoic cysts and limestone formations. The current carbonate limestone has a permeable structure and they are located at the areas near the sea. Bodrum peninsula is observed to be quite poor in terms of water resources. The reasons for this include the fact that there are arid and semiarid climate conditions for the duration of six months in the region and that transient limestone formation take up a large amount of space [37]. The water requirements of the Bodrum Peninsula have been provided from five different supplies since 2011 (Figure 1, Table 1).

These sources are Geyik dam, Mumcular dam, Çamköy groundwater wells, Karaova groundwater wells and Bodrum groundwater wells. However, the source of the waters coming to the Bodrum peninsula treatment plant is Mumcular Dam, Geyik Dam and Çamköy groundwater wells.

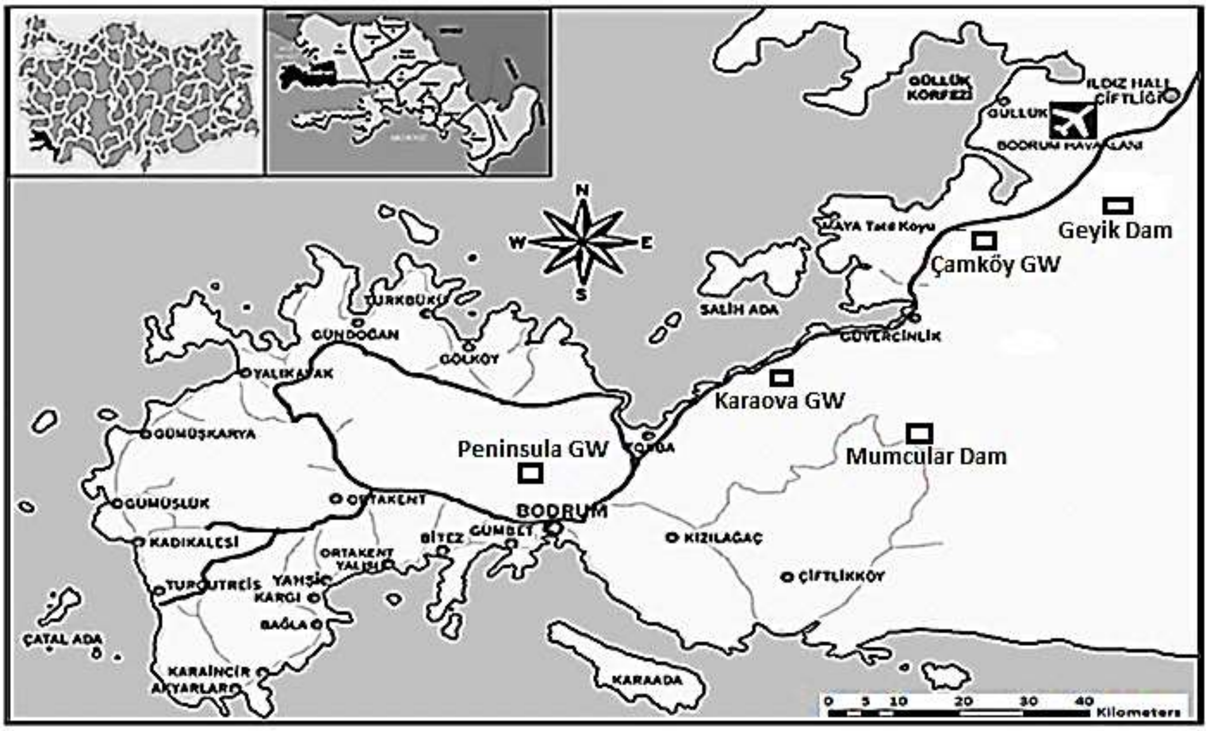

Figure 1. Water resources and location of the Bodrum peninsula in Turkey

Table 1. Water sources of Bodrum peninsula [38]
(GW: Groundwater Well, hm^3: million cubic meters)

Water Sources	Capacity (hm^3/year)
Mumcular Dam	5.00
Geyik Dam	5.00
Çamköy GW	4.72
Total	14.72

2.2. Method

In order to determine the drinking water quality of the Bodrum peninsula water sources, the water samples taken from Mumcular and Geyik dams and from Çamköy groundwater wells have been analyzed since 1995 by Aydın DSI XXI Regional Directorate for the purpose of examining the quality of drinking water in Bodrum [38]. The examined parameters were measured at three sampling sites between 1995 and 2015. Total of 22 physicochemical parameters were determined and analyzed in the Quality and Control Laboratory of XXI Regional Directorate for the purpose of examining the quality of drinking water in Bodrum peninsula. The untreated raw waters arrive at the treatment plant from Mumcular and Geyik dams and also from Çamköy groundwater wells. The blended raw waters obtained from Mumcular dam-Geyik dam-Çamköy groundwater wells, and from Geyik dam-Çamköy groundwater wells have been analyzed in conjunction with each other. The selected 22 parameters for this study were evaluated using the Water Quality Index (WQI) method. WQI aims to give a single outcome value to the water quality of the examined water source by converting the parameters list and their concentrations in a large sample into a single value [34]. WQI, very useful and efficient method, is calculated by using Weighted Arithmetic Index method as explained by [29]. According to this method, different water quality parameters are multiplied by a weighting factor determined for each parameter and summed using the simple arithmetic mean method. The WQI is calculated as per the quality standards of drinking water recommended by the World Health Organization (WHO). Calculation of WQI is conducted by following the Weight Arithmetic Index method [39], using the equations.

$$WQI=\sum Q_n W_n \sum W_n \quad (1)$$

Where,
Q_n: Quality rating of n^{th} water quality parameter,
W_n: Unit weight of n^{th} water quality parameter,
Q_n is calculated by the equation given below,

$$Q_n=[(V_n-V_i)(V_s-V_i)] \quad (2)$$

Where,
V_n: Actual value of n^{th} water quality parameters,
V_i: Ideal value of water quality parameters [V_i=0 except for pH (V_i=7), DO (V_i=14.6 mg/l)],
V_s: Standard permissible value for n^{th} water quality parameter,
W_n is calculated by the following formula,

$$W_n=k/V_s \quad (3)$$

Where,
k: Proportional constant, and calculated by the equation,

$$k=[1/\sum 1/V_{s=1,2,3.............n}] \quad (4)$$

Water Quality Status (WQS) determined as per to the WQI is presented in Table 2

Table 2. Possible uses and WQS corresponding to WQI values [39].

WQI	WQS	Usage Possibilities
0-25	Excellent	Drinking, irrigation, industrial
26-50	Good	Drinking, irrigation, industrial
51-100	Poor	Irrigation, industrial
76-100	Very Poor	Irrigation
Above 100	Unsuitable for drinking and fish culture	Proper treatment is required before use

3. RESULTS AND DISCUSSION

The blended raw water samples, taken from Mumcular dam, Geyik dam, Çamköy groundwater wells, and Geyik dam and Çamköy groundwater wells were analyzed according to the 22 physical and chemical parameters. The examined data reveal that Geyik dam, Mumcular dam and groundwater wells values of 16 parameters were well within the permissible limits for drinking water quality. The standard values, unit weight values, quality rating values and actualized average values of 22 parameters examined related to the blended raw waters of Mumcular dam-Geyik dam-Çamköy groundwater wells, and Geyik dam-Çamköy groundwater wells for calculation of WQI are given in Table 3.

The calculated WQI are 84.92 and 91.11 for the blended raw waters, respectively. The Water Quality Status is 'very poor' for both the blended raw water of Mumcular dam-Geyik dam-Çamköy groundwater and Geyik dam-Çamköy groundwater wells. Those values reveal that the status of the blended raw waters are unsuitable for human uses without treatment process, since they are in the range very poor class (70-100). Present blended raw waters can use only for irrigation according to Water Quality Status. In general, the results at sampling sites for blended raw waters indicate that the values of some parameters such as Chemical Oxygen Demand (COD), Turbidity, Biochemical Oxygen Demand (BOD), Dissolved Oxygen, and Total Hardness are beyond of permissible limits prescribed by WHO for drinking water standards [40]. These parameters have the greatest effect on the WQI scores. As Table 3 shows, COD and BOD are the two determining parameters that have the maximum effect in the calculation of WQI.

Table 3. The calculated WQI values for blended raw water of Mumcular dam-Geyik dam- Çamköy groundwater wells, and Geyik dam-Çamköy groundwater wells

WATER QUALITY INDEX FOR MEASURING DRINKING WATER QUALITY OF BODRUM PENINSULA-TURKEY

Parameters	Symbol	Unit	WHO Standard	Mumcular dam-Geyik dam-Çamköy groundwater wells				Geyik Dam-Çamköy groundwater wells			
				V_n	W_n	Q_n	W_n* Q_n	V_n	W_n	Q_n	W_n* Q_n
pH	pH	pH	8.5	7.8	0.034	53.33	1.812	7.60	0.034	40.00	1.359
Turbidity	Turb	NTU	5.0	8.4	0.058	168.00	9.702	4.40	0.058	88.00	5.082
Color	Col	Pt-Co	15	0.0	0.019	0.00	0.000	0.00	0.019	0.00	0.000
Electrical Conductivity	EC	µmhos/cm	300	300	0.001	100.00	0.096	300	0.001	100.00	0.096
Total Dissolved Solids	TDS	$mg.L^{-1}$	500	187	0.001	37.40	0.022	179	0.001	35.80	0.021
Chloride	Cl	$mg.L^{-1}$	250	22.8	0.001	9.12	0.011	20.6	0.001	8.24	0.010
Nitrite Nitrogen	NO_2-N	$mg.L^{-1}$	3.0	0.01	0.096	0.40	0.039	0.01	0.096	0.40	0.039
Ammonia Nitrogen	NH_3-N	$mg.L^{-1}$	1.5	0.19	0.193	12.80	2.464	0.38	0.193	25.33	4.877
Nitrate Nitrogen	NO_3-N	$mg.L^{-1}$	50	0.65	0.006	1.30	0.008	1.90	0.006	3.80	0.022
Dissolved Oxygen	DO	$mg.L^{-1}$	6.0	8.90	0.048	66.28	3.190	9.30	0.048	61.63	2.966
Organic Material	Pv	$mg.L^{-1}$	5.0	5.14	0.058	102.80	5.937	5.11	0.058	102.20	5.902
Biochemical Oxygen Demand	BOD_5	$mg.L^{-1}$	3.0	6.8	0.096	226.67	21.817	7.90	0.096	263.33	25.347
Chemical Oxygen Demand	COD	$mg.L^{-1}$	5.5	39.4	0.053	716.36	37.610	45.20	0.053	821.82	43.147
Total Hardness	TH	$mg.L^{-1}$	60	139.2	0.005	232.00	1.117	141.5	0.005	235.83	1.135
Orthophosphates	O-PO_4	$mg.L^{-1}$	5.0	0.07	0.058	1.40	0.081	0.01	0.058	0.20	0.012
Sulphates	SO_4	$mg.L^{-1}$	250	18.7	0.001	7.48	0.009	21.9	0.001	8.76	0.010
Sodium	Na	$mg.L^{-1}$	200	9.87	0.001	4.94	0.007	9.29	0.001	4.65	0.007
Potassium	K	$mg.L^{-1}$	12	2.37	0.024	19.75	0.475	1.91	0.024	15.92	0.383

Calcium	Ca	$mg.L^{-1}$	200	41.9	0.001	20.95	0.030	58.2	0.001	29.10	0.042
Magnesium	Mg	$mg.L^{-1}$	50	8.80	0.006	17.60	0.102	7.60	0.096	2.20	0.212
Copper	Cu	$mg.L^{-1}$	2.0	0.03	0.144	1.65	0.238	0.05	0.144	2.45	0.354
Zinc	Zn	$mg.L^{-1}$	3.0	0.05	0.096	1.57	0.151	0.07	0.006	15.20	0.088
WQI							**84.92**				**91.11**

In the peninsula, the observed turbidity values have been above the permissible value for the blended raw water of Mumcular dam, Geyik dam and Çamköy groundwater wells. The turbidity has been come from the clay and chalk particles on the water stored in Mumcular and Geyik dams, insoluble precipitations which can be with related its karstic origin, and human activity in the region. According to the study conducted by [41] in Ghana, turbidity value in the small scale dams are extremely higher, and the high level of turbidity in the dam water could be owing to the accumulation of particulate matter through runoff from increased precipitation. [42] stated that the raw water samples are usually colored owing to the existing of colloidal substance, aquatic growth, inorganic impurity and decomposition of vegetation. The high turbidity values observed in the study indicate that there is no filtering process in the existing water resources. Therefore, the turbidity will need to be improved with the water treatment process consisting of tank and filter

BOD shows the extent of pollutant in the water body, and is the amount of dissolved oxygen needed for the biochemical decomposition of organic compounds and the oxidation of some inorganic materials [43]. COD is a measure of water quality used to measure the amount of biologically active substances, such as bacteria, as well as the amount of biologically inactive organic matter in the water [44]. Theoretically, if COD value in water is higher, then the water is considered polluted water [45]. COD and BOD values of both Mumcular dam water and specially Geyik dam water are higher according to the WHO standards. Particularly, Geyik dam is heavily polluted water. The important reason for this is because of the fact that industrial wastes especially from olive oil factories in the region and domestic wastes are released into the drainage area of Geyik and Mumcular dams without any filtering process. The high values of BOD may be indicative of fecal and organic waste contamination from human and animal sources, which restricts the use of water for drinking and domestic purposes. An increase in BOD causes a potential health threat to the people, using the water with high BOD for drinking water. High COD can result from leaching of chemically degradable organic and inorganic waste matter coming from intensive populated surrounding area. In India, [46] reported that three dams are polluted to some extent but Kerwa dam is most polluted as indicated by a very high value of COD. The main sources of pollution of Kerwa dam are the human settlement around the dam and their activities. A study, conducted by [47] in Aksu River, Turkey put forth that COD values increase due to the industrial and agricultural activities in the locality. The utilization of pre-ozone treatment, settlement tank, filter, final ozone treatment and granular active carbon filters will help to improve these values. Total hardness values of three different water sources are above of the limit value. Therefore, there is special need for a process to reduce the total hardness.

The Peninsula Water Treatment Plant, which treats the raw waters that are blended from Çamköy groundwater wells and from the Mumcular and Geyik dams, should have the equipment to control the parameters such as turbidity, BOD, COD, Dissolved Oxygen and Total Hardness. Therefore, the operations selected for treatment processing comprise of coagulation, aeration, precipitation, flocculation, filtration and disinfection.

4. CONCLUSION AND RECOMMENDATIONS

WQI method is very useful for evaluation and management of water quality. This study reveals an important research on Bodrum peninsula water sources to be used as drinking water. The study also provides a valuable perspective on the status of Bodrum peninsula water sources according to the calculated WQI values. It emphasizes the spectral characteristics of physical and chemical parameters which affect the quality of peninsula water sources. Calculated WQI values were examined according to the blended raw waters for the peninsula water sources. The basic data produced in these studies and their analysis and interpretation will help to improve our understanding and knowledge about the status of water quality in the peninsula and factors effecting the quality of the water. The WQI values suggests that the blended raw water quality of the peninsula is not suitable for drinking purposes without making treatment processes and is only fit for irrigation because some parameters such as Turbidity, COD, BOD, Dissolved Oxygen and Total Hardness are not within the WHO standards.

According to the calculated WQI results, it can be concluded that effective measures should be taken urgently to use efficiently the existing water resources of the peninsula by establishing an appropriate water quality management plan supporting the sustainable drinking water.

In addition to the treatment process, water quality of Mumcular and Geyik dams needs to be improved by adapting measures such as limiting the sewerage sludge from residential and commercial establishments, preventing the wastes from agricultural facilities, limiting direct discharge from rainwater drains to the dam lake and preventing the unloading of solid wastes by the communities living in the dam region.

REFERENCES

[1] PESCE, S.F., WUNDERLIN, DA., "Use of water quality indices to verify the impact of Córdoba city (Argentina) on Suquía River". Water Research 34. 2915-2926, 2000.

[2] DIERSING, N., "Water Quality: Frequently Asked Questions". Florida Keys National Marine Sanctuary, Key West, FL. Available at: http://floridakeys.noaa.gov/scisummaries/wqfaq.pdf. 2009

[3] SARGAONKAR, A., DESHPANDE, V., "Development of an overall index of pollution for surface water based on a general classification scheme in Indian context". Environmental Monitoring and Assessment 89, 43–67, 2003.

[4] KHAN, F., HUSAIN, T., LUMB, A., "Water quality evaluation and trend analysis in selected watersheds of the Atlantic Region of Canada". Environmental Monitoring and Assessment. 88, 221–242, 2003.

[5] REZA, R., SINGH, G., "Assessment of Ground Water Quality Status by Using Water Quality Index Method in Orissa, India". World Applied Sciences Journal 9, (12) 1392-1397, 2010.

[6] MICHALIC, A., "The Use of Chemical and Cluster Analysis for Studying Spring Water Quality in Świętokrzyski National Park". Polish Journal of Environmental Studies, 17 (3) 357-362, 2008.

[7] ROBLES, E., RAMIREZ, E., MARTINEZ, B., SAINZM, M.G., GONZALEZ, M.E., "Comparison of the Water Quality of Two Aquifers Established in Different Development Zones of Mexico". Universal Journal of Environmental Research and Technology, 1 (2), 203-211, 2011.

[8] GLINSKA-LEWCZUK, K., "Effect of Land Use and Lake Presence on Chemical Diversity of the Lyna River System". Polish Journal of Environmental Studies, 15 (2) 259-269, 2006

[9] KASIROVA, S., FESZTEROVA, M., "Changes in Stream Water Contamination in Select Slovakian Settlements". Polish Journal of Environmental Studies, 19 (2), 343-349, 2010

[10] AYDIN, A., "The Microbiological and Physico-Chemical Quality of Groundwater in West Thrace, Turkey". Polish Journal of Environmental Studies. 16 (3), 377-383, 2007.

[11] NAS, S.S., BAYRAM, A., NAS, E., BULUT, V.N., "Effects of Some Water Quality Parameters on the Dissolved Oxygen Balance of Streams". Polish Journal of Environmental Studies 17 (4), 531-538, 2008.

[12] ALMEIDA, C.A, QUINTAR, S., GONZALEZ, P., MALLEA, M.A.," Influence of urbanization and tourist activities on the water quality of the Potrero de los Funes River (San Luis-Argentina)". Environmental Monitoring and Assessment 133, 459-465, 2007.

[13] ASADI, S.S., VUPPALA, P., ANJI, R.M., "Remote sensing and GIS techniques for evaluation of groundwater quality in Municipal Corporation of Hyderabad (Zone-V)". India. Int. J. Environ. Res. Public Health 4, 45-52, 2007.

[14] BUCHANAN, S., TRIANTAFILIS, J., "Mapping water table depth using geophysical and environmental variables". Groundwater 47, 80. 2009.

[15] SAMANTRAY, P., MISHRA, B.K., PANDA, C.R., ROUNT, S.P., "Assessment of water quality index in Mahanadi and Atharabanki Rivers and Taldanda Canal in Paradip area". India. J Hum Ecol 26 (3), 153–161, 2009.

[16] SHARMA, D., KANSAL, A., “Water quality analysis of River Yamuna using water quality index in the national capital territory India (2000-2009)”. Applied Water Science 1,147-157, 2011.
[17] ALAM, M., PATHAK, J.K., “Rapid assessment of water quality index of Ramganga River, Western Uttar Pradesh (India) using a computer programme”. Nat Sci 8 (11), 1-8, 2010.
[18] SEBASTIAN, J., YAMAKANAMARDI, S.M., “Assessment of water quality index of Cauvery and Kapila Rivers and at their confluence”. Int J Lakes Rivers 6(1), 59-67, 2013
[19] SETH, R., MOHAN, M., SINGH, P., SINGH, R., DOBHAL, R., SINGH, K.P., GUPTA, S., “Water quality evaluation of Himalayan Rivers of Kumaun region, Uttarakhand, India”. Appl Water Sci 6 (2), 137-147, 2014.
[20] TYAGI, S., SHARMA, B., SINGH, P., DOBHAL, R., “Water quality assessment in terms of water quality index”. Am J Water Resour 1(3), 34–38. 2013.
[21] BHUTIANI, R., KHANNA, D.R., KULKARNI, D.B., RUHELA, M., “Assessment of Ganga river ecosystem at Haridwar, Uttarakhand, India with reference to water quality indices”. Appl Water Sci 6 (2), 107-113, 2014.
[22] VISHNURADHAN, R., ZAINUDIN, Z., SREEKANTH, J.B., DHIMAN, R., SALLEH, M.N., VETHAMONY, P., “Temporal water quality response in an urban river: a case study in peninsular Malaysia”. App Water Sci 7(2), 923-933, 2015.
[23] YADAV, K.K., GUPTA, N., KUMAR, V., SHARMA, S., ARYA, S., “Water quality assessment of Pahuj River using water quality index at Unnao Balaji, M.P., India”. Int J Sci Basic Appl Res 19(1), 241-250. 2015.
[24] DASH, A., DAS, H.K., MISRA, B., BHUYAN, N.K., “Evaluation of water quality of local streams and Baitarani River in Joda area of Odisha”. India. Int J Curr Res 7(3) 13559-13568. 2015.
[25] KRISHNAN, G., SINGH, S., SINGH, R.P., GHOSCH, N.C., KHANNA, A., “Water quality index of groundwater of Haridwar District, Uttarakhand, India”. Water Energy Int 58(10), 55-58, 2016.
[26] KAVIARASAN, M., GEETHA, P., SOMAN, K.P., “GIS-based groundwater monitoring in Thiruvannamalai District, Tamil Nadu, India”. In: Proceedings of International Conference on Soft Computing Systems, vol. 397, Springer, India, pp 685-700, 2016
[27] AKOTEYON, I.S., OMOTAYA, A.O., SOLADOYE, O., OLAOYE, H.O., “Determination of water quality index and suitability of urban river for municipal water supply in Lagos, Nigeria”. Eur J Sci Res 54(2), 263-271. 2011.
[28] BALAN, I.N., SHIVAKUMAR, M., KUMAR, P.D.M., “An assessment of groundwater quality using water quality index in Chennai, Tamil Nadu, India”. Chron Young Sci 3(2) 146-150, 2012.
[29] CUDE, C., “Oregon water quality index: A tool for evaluating water quality management effectiveness”. Journal of the American Water Resources Association 37, 125-137, 2001.
[30] LIOU, S., LO, S., WANG, S., “A generalized water quality index for Taiwan”. Environmental Monitoring and Assessment 96, 35-52, 2004.
[31] SAID, A., STEVENS, D., SELKE, G., “An innovative index for evaluating water quality in streams”. Environmental Management 34, 406-414, 2004.
[32] DEBELS, P., FIGUEROA, R., URRUTIA, R., BARRA, R., NIELL, X., “Evaluation of water quality in the Chilla’n River (Central Chile) using physicochemical parameters and a modified water quality index”. Environmental Monitoring and Assessment 110, 301-322, 2005.
[33] KANNEL, P.R., LE, S., LEE Y.S., KANEL, S.R., KHAN, S.P., “Application of water quality indices and dissolved oxygen as indicators for river water classification and urban impact assessment”. Environmental Monitoring and Assessment 132, 93–110, 2007.
[34] ABBASI, S.A., “Water quality indices”, state of the art report (pp. 73). Scientific Contribution No. INCOH/SAR-25/2002. Roorkee: INCOH, National Institute of Hydrology, pp. 77, 2002
[35] GOR, A., SHAH, A., “Water Quality Index of Mahi River, Vadodara, Gujarat”. International Journal of Engineering Development and Research 2(3), 3214-3219, 2014.
[36] DAN’AZUMI, S., BICHI, M., “Industrial pollution and heavy metals profile of Challawa River in Kano. Nigeria”. Journal of Applied Sciences and Environmental Management, Sanitation 5, 2010.
[37] DSI. Bodrum İçmesuyu Projesi. Orman ve Su İşleri Bakanlığı. Devlet Su İşleri Vakfı. Su Dünyası Dergisi 99, 12-20, 2011.
[38] DSI. Planning Report of Bodrum Peninsula Emergency Drinking, Potable and Industry Water Supply Project. Ministry of Forestry and Water Affairs. General Directorate of State Hydraulic Works. XXI. Regional Directorate, 435 pp. Aydın. 2009
[39] BROWN, R.M., MCCLELLAND, N.I., DEININGER, R.A., O’CONNOR, M.F., “A water quality index-crashing the physiological barrier”. Indic Environ Qual 1, 173–182, 1972.

[40] WHO. Guidelines for Drinking-Water Quality, 4th ed.; World Health Organization (WHO): Geneva, Switzerland. 2012
[41] KPIETA, B.A., LAARI, B.P., "Small-scale dams water quality and the possible health risk to users of the water in the Upper West Region of Ghana". European Scientific Journal, 10 (14), 249-270, 2014
[42] YATES, B.J., ZBORIL, R., SHARMA, V.K., "Engineering aspects of ferrate in water and wastewater treatment–a review". Journal of Environmental Science and Health, Part A. 49 (14), 2014.
[43] KUMAR, S., GNUSH, N.C., SINGH, R.P., MAHESH, M., SONKUSARE, S.S., SANYAJ, M., "Assessment of Water Quality of Lakes for Drinking and Irrigation Purposes in Raipur City, Chhattisgarh, India". pp.42-49, 2015
[44] KHUHAWARI, M.Y., MIRZA, M.A., LEGHARI, S.M., ARAIN, R., "Limnological study of Baghsar Lake district Bhimber, Azad Kashmir". Pakistan Journal of Botanic, 41(4), 1903–1915, 2009.
[45] AMNEERA, W.A., NAJIB, W.A.Z., YUSOF, S.R.M., RAGUNATHAN, S., "Water quality index of Perlis River, Malaysia". Int. J. Civ. Environ. Eng. 13 (2), 1–6, 2013.
[46] CHOUDHARY, R., RAWTANI, P., VISHWAKARMA, M., "Comparative study of Drinking Water Quality Parameters of three Manmade Reservoirs i.e. Kolar, Kaliasote and Kerwa Dam". Current World Environment6 (1), 145-149, 2011.
[47] ŞENER, Ş., ŞENER, E., DAVRAZ, A., "Evaluation of water quality using water quality index (WQI) method and GIS in Aksu River (SW-Turkey)". Science of the Total Environment 584–585, 131–144, 2017.