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Water Quality Index (WQI) for Main Source of Drinking Water (Karaçomak Dam) in Kastamonu City, Turkey

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Abstract

Karaçomak Dam is main source of drinking water in Kastamonu city (Turkey) for this reason, In this study used Water quality index which provides a single value to express overall quality based on 13 variables that were determined during the period between September 2015 until July 2016. Sampling points chosen as described by first station at intake point of the drinking water supply for Kastamonu city, second station was opposite intake point of the drinking water supply about (449) m along at main dam. The parameters namely Electrical Conductivity (EC), pH, Temperature (T), Dissolved oxygen (DO), Turbidity (TUR), Total hardness (Ha), Total alkalinity, Ammonia nitrogen (NH_4-N), Nitrite nitrogen (NO_2-N), Nitrate nitrogen (NO_3-N), Phosphate (PO_4-P), Biochemical oxygen demand (BOD), Chemical oxygen demand (COD) were analyzed according to Standard Methods for the Examination of Water and Wastewater. The resulted WQI shows that (35.5 and 32.4) for sites (S1 and S2) respectively. On the other hand, there was significant temporal variations in water quality index among poor quality to excellent quality whereas that January 2016 showed high level of deterioration at (S1, S2), this may be due to starting the winter 2016 where high contribution from runoff at downstream areas which increase of deterioration body water in the Dam. The results clearly show that Water Quality index (WQI) was useful tool to obtain the right decision and evaluating water quality. In future, evaluation of water quality in Karaçomak dam should be given main priority of using the microbiological parameters with physico-chemical parameters in WQI calculations and to water quality monitoring.

Keywords: Water quality index; Physico-chemical parameters; Kastamonu; Karaçomak dam

Introduction

Ecosystem forms are a prime natural resource and valuable national resource and water. The Water sources is often mainly in types of streams, lakes, glaciers, rainfall or ground water. Water is one of the most essential elements for all existing organism on this planet earth. The quantity and quality of water both surface or ground water have been deteriorated as a result of some significant points such as growing population, industrialization and social process [1-4]. Water quality is defined as all an information of biological, chemical, and physical elements of water and their interaction to decide the suitable usage for water [5]. In fact, described water quality dependent on which kind of using. For example, water utilized for irrigation must be completely minimal in dissolved minerals to avoid salination of soils; water for recreation using should reach criteria for fecal coli forms; and potable water must be safe for drinking and cleaning [6-8]. Therefore, traditional method of water quality assessment can be described as the analysis of the biological, chemical, and physical properties of water in guide to natural quality, human health impacts, and wanted uses [9,10]. For instance, The Physico-chemical parameters and some metal concentrations were measured to determine the water quality of the Beyler Reservoir Kastamonu-Turkey that the reservoir has a considerably high quality water [11]. Furthermore, [12] studied an evaluation of lake Uluabat-Turkey. On the other hand, water quality monitoring of surface water will help protect our waterways from pollution. Likewise, the monitoring to our source water that the best way to understand and to avoid pollution problems [13]. According to [14] has done evaluate the impacts of seasonal differences on sampling points of Karasu-Sarmisakli Creeks and Kizilirmak River in Kayseri-Turkey. In general, Water Quality Index (WQI) is a statistical functional tool for simplifying, detailed and describing complex information collected from any body of water which reflects the integrated influence on the overall quality variables this value is understandable and use by the decision makers, planer and the general public [15,16]. So, quality index (WQI), which is one of the most successful methods to describe the quality of water. Actually, many of WQIs using different variables relying on the water quality goals all over the world [10,17]. The Karaçomak dam is the most very important water supply in the Kastamonu of Turkey and Karaçomak Dam plays an important role in water supply which was built in 1973 helps as the major source of water for residents of Kastamonu Municipality in Upper North Region of Turkey. Water dam stored in reservoir tanks and then distributed to residents through distribution pipe lines after treated by the Kastamonu Water Company. But, some residents in neighborhoods the dam resort to the untreated water from the dam as their source of drinking water particularly when they go to their farms.

The objective of this study was to create a WQI for the water in the Karaçomak dam located in Kastamonu, turkey. These results are of vital importance to local residents who will have a general knowledge of the water quality in their region during a specific period of time, instead of attempting to understand complex water quality data. For the same objective, an annual spatiotemporal difference of water quality indices of the surface waters around the capital city of Turkey, Ankara, is evaluated using the CWQI, OWQI [18]. At the same time,

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using this index will provide important information to decision makers as to whether it is a benchmark-success or failure.

Materials and Methods

Description of the study area

The study area is the main source of drinking water for Kastamonu area where exist Karaçomak dam. Geographically, Karaçomak dam is located at latitudes (41° 19' 07.56" to 41° 17' 29.27" N), and longitudes (33° 44' 41.38"-33° 44' 06.32" E) in Kastamonu city, Turkey, and elevated 887-904 m above sea level. In an attempt to continue to the proposed aims of this study, two sites were chosen for sample collection at the study area (Figure 1).

Site one (S1) was selected from Karaçomak dam at the intake of the drinking water supply for Kastamonu city with a GPS coordinates and elevation of (41° 19' 05.84" N and - 33° 44' 35.56" E -893 m). Site two (S2) was opposite the intake of the drinking water supply for Kastamonu city with GPS coordinates and elevation of (41° 18' 59.63" N and - 33° 44' 51.04" E-897 m) The overall distance between the sample site S1 to sample site S2 was about (449) m along at main dam.

Sampling and sample preparation

Water samples were taken from two sites every two months starting in September 2015 until July 2016. Samples were collected at 30 cm depth from the surface: All measurements were carried out in triplicate, and the results were expressed as averages. The measurement at sampling site, Dissolved oxygen, Electric conductivity, Turbidity, pH and water temperature were recorded. The water samples were held in ice boxes and immediately transported to laboratory of Kastamonu university for analysis of water quality following common protocols.

Sample analysis

Electrical conductivity (EC), pH, temperature (T) and dissolved oxygen (DO) were measured locally by (HQ40d Portable pH, Conductivity, Dissolved Oxygen Multi-Parameter Meter) field instruments (Hach Company). Turbidity (TUR) was measured using WTW Turb 430 IR model with highest precision according to US EPA for water analytics, quality control and process monitoring. Total hardness (Ha) and total alkalinity were determined by volumetric titrimetry. Ammonia nitrogen (NH4-N), nitrite nitrogen (NO2-N), nitrate nitrogen (NO3-N), Phosphate (PO4-P) were determined using a HACH-DR 6000 UV-Vis Spectrophotometer. Biochemical oxygen demand (BOD) was determined by five days incubation and chemical oxygen demand (COD) with open reflux method. All of the water quality parameters were analyzed according to Standard Methods for the Examination of Water and Wastewater [19,20].

Figure 1: Karaçomak dam shows location of sample collection at the study area.

Technique of water quality index (WQI)

The statistical analysis was done for descriptive statistics using (SPSS Version 19.0 for Windows 2008). Table 1 shown the statistics of the Physico-Chemical Parameters in Karaçomak dam.

The computation of the WQI, the weighted arithmetic index method of the parameter was implemented from many literatures [21-23].

The WQI considered is of the form:

$$WQI = \sum_{i=1}^{n} \frac{Wiqi}{\sum Wi} \quad (1)$$

qi=Quality rating for the ith water quality parameters

Wi: Unit weight for the ith parameters

For doing the calculation of WQI in this study requires four steps:

- **Firstly step** is parameter selection thirteen variables were selected to calculate the WQI utilizing the standards of drinking water quality recommended by the World Health Organization (WHO) and Water Pollution Control Statement of Regulation Turkish (WPCSR) shown Table 1 (Amendment Table 1: RG-13/2/2008-26786) [24].
- **Secondly step** is Computation of sub index of quality rating (qi)

According to Brown et al., quality rating or sub index (qi) was calculated using the following

expression: $$q_i = \left(\frac{(V_a - V_i)}{(V_s - V_i)}\right) \times 100 \quad (2)$$

q_i=Quality rating for the ith water quality parameters

V_a: actual value present of the (ith) parameter at a given sampling station.

V_i: ideal value (0 for all parameters excepts pH and DO which are 7.0 and 14.6 mg/lit respectively).

V_s: standard value

If quality rating=zero that means complete absence of pollutants. While, quality rating $0<q_i<100$ implies that, the pollutants are above the standards [25].

- **Thirdly step** is Computation of unit weight (relative weight calculation)

The Unit weight (W_i) to different water Quality parameters are inversely relative to the recommended standards value for the related parameters.

$$W_i = \frac{k}{s_i} \quad (3)$$

w_i: unit weight for the ith parameters

s_i: standards value for the ith parameters

k: relative constant

This value considered (1) here, also can calculate using the following equation:

Parameters	Standard values	Station (S1) n=18			Station (S2) n=18		
		Min	Max	Std. Dev.	Min	Max	Std. Dev.
EC	1500	431	471	12.69	419	475	16.99
pH	6.5-8.5	8.51	8.77	0.07	8.48	8.91	0.14
Temperature	25	5.3	19.8	5.57	4.7	19.5	5.7
Turbidity	5 NTU (WHO)	2.0	7.5	1.7	2.4	8.4	1.9
T. Hardness	500	91.8	97.7	1.7	91.6	95.4	1.13
Alkalinity	120 (WPCSR)	28.5	29.3	0.2	28.1	30.1	0.71
DO	8 (WPCSR)	7.3	11.8	1.7	6.4	12.9	2.1
BOD	4 (WPCSR)	2.1	16.1	5.07	2.56	19.3	6.06
COD	25 (WPCSR)	2.1	15.4	4.3	3.7	24.9	7.39
NH_4-N	0.2 (WPCSR)	0.025	0.136	0.033	0.023	0.138	0.040
NO_3-N	5 (WPCSR)	0.09	0.7	0.182	0.09	0.65	0.172
NO_2-N	1 (WHO)	0.004	0.013	0.0025	0.001	0.01	0.002
PO_4-P	0.1 (WHO)	0.02	0.11	0.029	0.01	0.090	0.025

Table 1: Statistics of chemical parameters (all in mg/l and EC in µS/cm) in Karaçomak dam.

WQI Value	Rating of water quality	Grading
0-25	Excellent water quality	A
26-50	Good water quality	B
51-75	Poor water quality	C
76-100	Very poor water quality	D
Above 100	Unsuitable for drinking purpose	E

Table 2: The levels of water quality index.

Parameters	Standard values	Station (S1)						Station (S2)					
		Sep	Nov	Jan	March	May	July	Sep	Nov	Jan	March	May	July
pH	6.5-8.5	8.59	8.67	8.55	**8.75**	8.66	8.64	8.69	8.59	8.49	**8.87**	8.86	8.74
EC	1500	439.6	459.0	465.6	448.3	436.6	434	432.3	458.3	469	440	423.3	430.6
Temperature	25	19.4	10.5	5.7	5.5	11.7	18.1	19.4	10.1	4.9	5.26	11.2	17.6
T. Hardness	500	92.7	91.9	96.9	95.8	93.9	93.75	94.3	91.86	95.1	95	94	94.01
NH_4-N	0.2(WPCSR)	0.027	0.1	0.13	0.081	0.076	0.089	0.026	0.095	0.13	0.024	0.086	0.089
NO_3-N	5(WPCSR)	0.09	0.27	0.3	0.32	0.37	0.68	0.1	0.19	0.31	0.38	0.39	0.6
NO_2-N	1 (WHO)	0.004	0.008	0.011	0.007	0.006	0.004	0.003	0.007	0.008	0.006	0.004	0.003
PO_4-P	0.65(WPCSR)	0.08	**0.10**	0.046	0.021	0.039	0.07	0.07	**0.086**	0.05	0.016	0.03	0.069
Alkalinity	120(WPCSR)	28.9	29.04	28.9	29.1	28.6	28.7	29.4	28.83	29.9	28.5	28.1	29.8
Turbidity	5NTU(WHO)	2.75	2.72	2.13	**7.05**	4.18	3.26	3.1	2.65	2.52	**8.01**	3.44	3.48
DO	8 (WPCSR)	7.41	7.42	8.59	**11.45**	**11.49**	10.02	7.47	6.45	9.46	**12.5**	**11.13**	10.3
COD	25 (WPCSR)	15.2	8.4	6.42	10.0	2.7	3.23	24.7	6.63	3.65	12.1	4.36	7.4
BOD	4 (WPCSR)	4.6	2.9	**15.56**	-	2.53	3.87	6.17	7.15	**19.0**	-	2.63	4.1

All the Parameters Value are Expressed in mg/l; Except pH, Turbidity (NTU), Conductivity EC (µS cm^{-1})

Table 3: Average the Physico-Chemical Parameters Water throughout the Study Period from September 2015-July 2016 for Karaçomak dam.

$$k = \frac{1}{\sum\left[\frac{1}{si}\right]} \tag{4}$$

- **Fourthly step** is the computed WQI values are categorized into five groups is given in Table 2 which The levels of water quality index, the best value of water quality was given a low range and the bad levels a higher number [26].

Results and Discussion

The statistical analysis of the surface water of Karaçomak Dam was done to determine the chemical parameters that are deviating from WHO drinking water standard and Water Pollution Control Statement of Regulation Turkish (WPCSR) shown Tables 1 and 3. It was observed that the mean, min, max and Standard deviation for all parameters in the untreated surface water in Karaçomak dam.

The physicochemical variables of water quality

The physicochemical variables of water quality were analyzed using standard methods given in APHA (American Public Health Association) that were within the limits of the standard used. however, with exception of (pH, Turbidity, DO, BOD and PO4-P) had exceeded the acceptable limits of the standard in some months during the study period. Analytical outcomes obtained for various study variables at two sites in different times of the year 2015-2016 are summarized in Table 3 are discussed below (Figures 2-15).

The pH of natural water is the greatest point of the water quality and the extent contamination in the watershed areas. results obtained from the current study showed that kept between 8.49 and 8.87 and decreased relatively at January compared with average concentration of pH in march and April (rainy season) demonstrates a gradual increase probably due to runoff from farming area and photosynthetic activity during spring period at watershed of Karaçomak dam [27]. The average of EC values for the researched durations ranged between (423.3 to 465.6 µS cm^{-1}) at sites S1 and S2. Table 3 which were lower than the recommended level (1500 µS cm^{-1}) by Water Pollution Control Statement of Regulation Turkish (WPCSR) (Amendment Table 1:

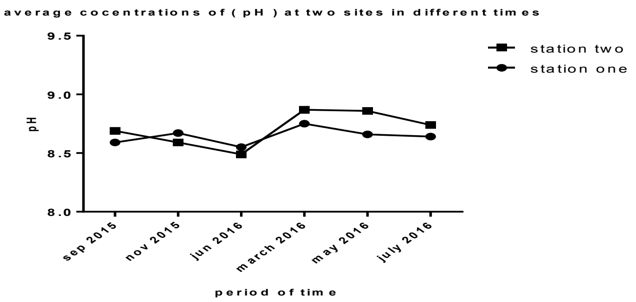

Figure 2: Average concentration of (pH).

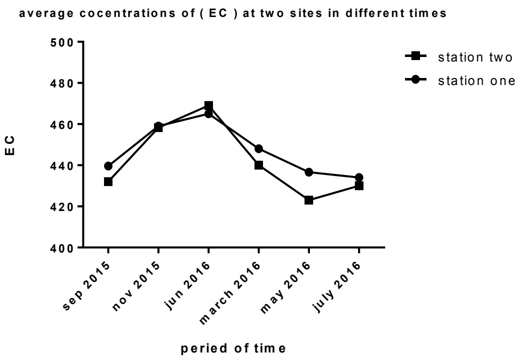

Figure 3: Average concentration of (EC).

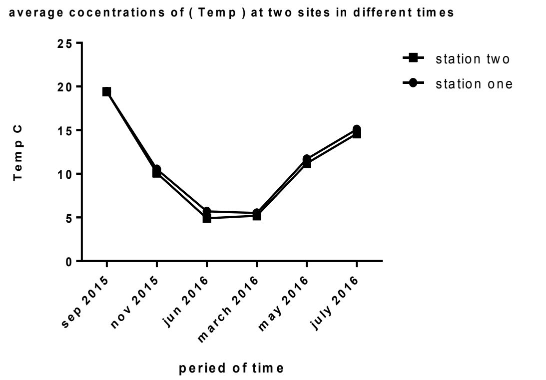

Figure 4: Average concentration of (Temp).

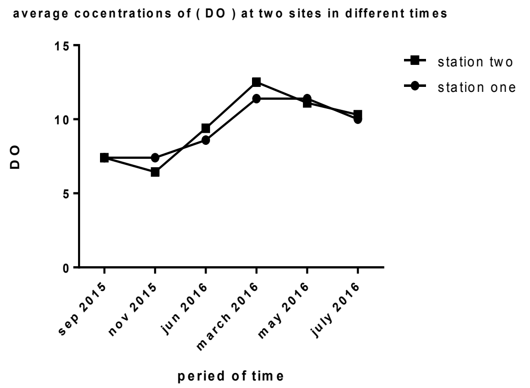

Figure 5: Average concentration of (DO).

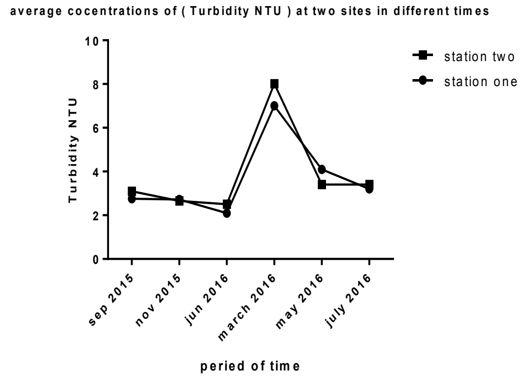

Figure 6: Average concentration of (Turbidity).

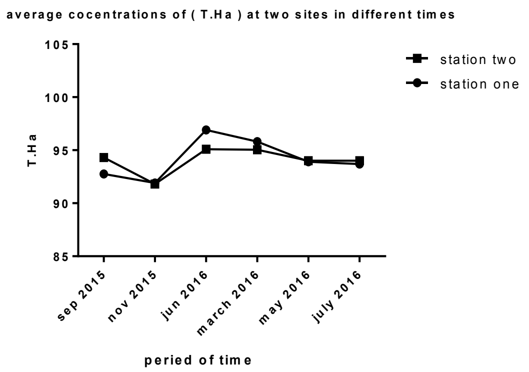

Figure 7: Average concentration of (T.Ha).

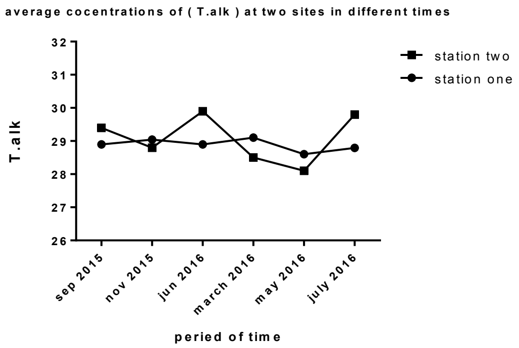

Figure 8: Average concentration of (T.alk).

RG-13/2/2008-26786) and WHO [24]. The results demonstrated those waters were suitable for drinking according on WHO (1500 µS cm^{-1}) [24]. Water temperature value and dissolved oxygen value are an important points to determining the water quality. in the Figure 4. The Water temperature values increased in July and September with (19.4°C, 17.6°C) compared to other months with (4.9°C, 5.5°C). In contrast, the average dissolved oxygen in the Figure 5 was reduced during July, September, November with (10.3 mg/l, 7.4 mg/l, 6.45 mg/l) which may be due to the rate of biodegradation and biological activity increases with the increase in the water temperature. In this study DO values noticed in Karaçomak Dam decreased in summer months while they increased in rainy season. Alike discovering was also mentioned for lake Pamvotis (Greece) by [28]. Turbidity of water Figure 6 at sites

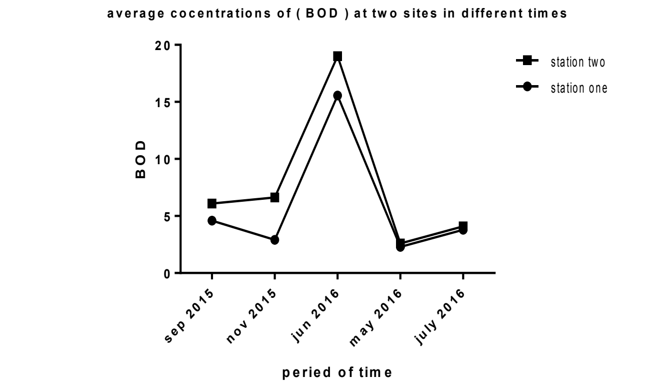

Figure 9: Average concentration of (BOD).

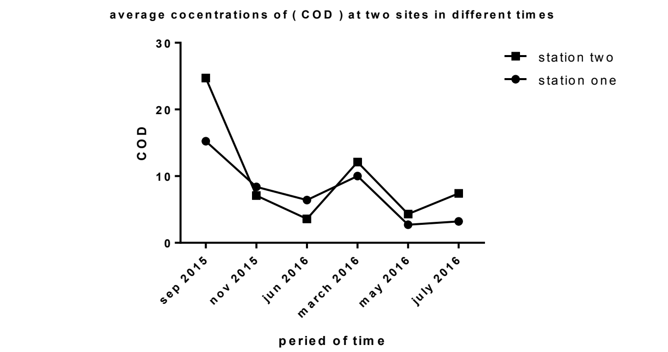

Figure 10: Average concentration of (COD).

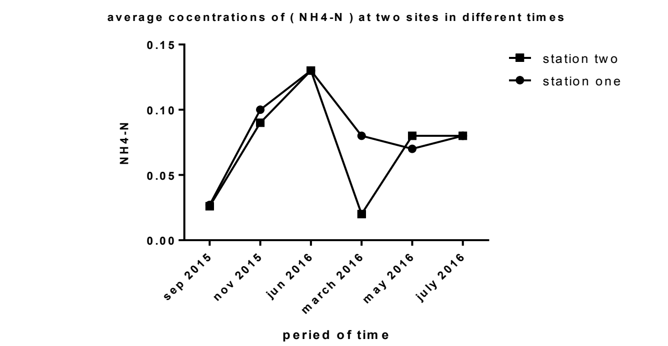

Figure 11: Average concentration of (NH_4-N).

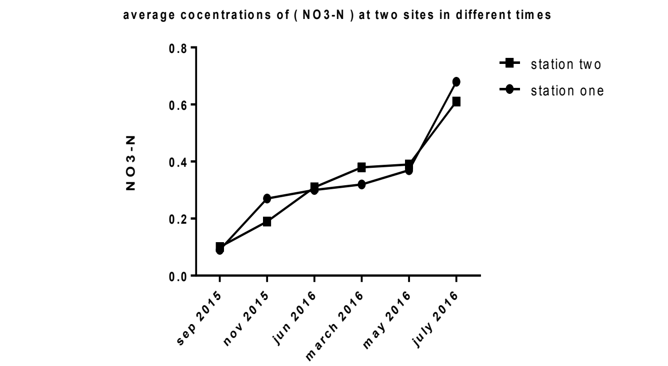

Figure 12: Average concentration of (NO_3-N).

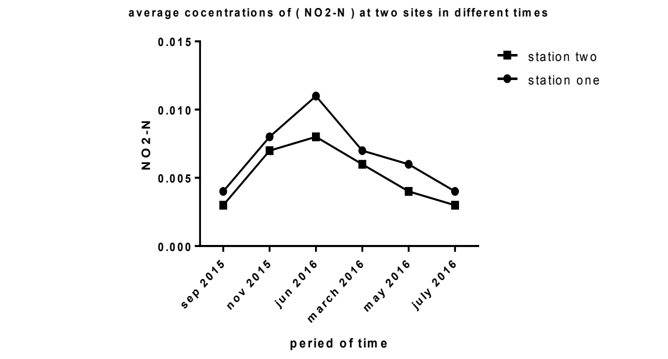

Figure 13: Average concentration of (NO_2-N).

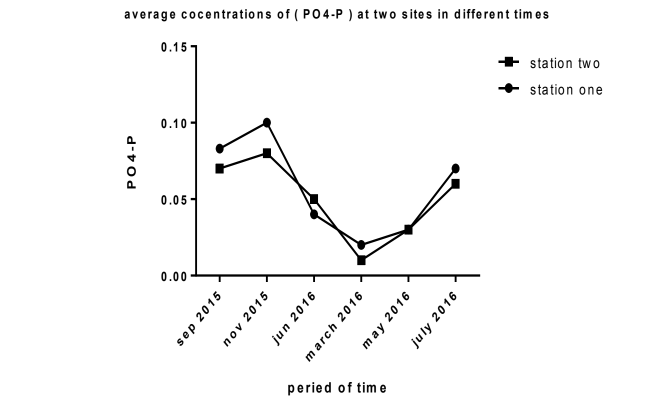

Figure 14: Average concentration of (PO4-P).

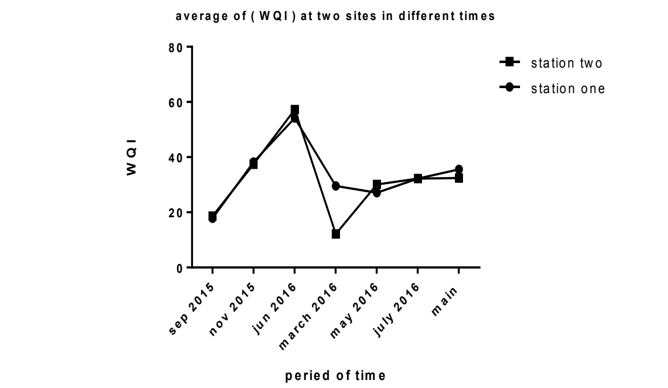

Figure 15: Average concentration of (WQI).

S1 and S2 shows that turbidity was higher in the March with 6.70 NTU and then it was lowered to reach levels of 2.13 NTU averaged during other months of the year. The turbidity comes from clay particles within the eroded soil in any catchment area this is because after the rainfall events the water is rich in organic matter and clay particles. The hardness of water is generally determined by the amount of calcium and magnesium salt. Hardness level of water is associated to geological construction contact throughout watershed [12]. hardness values in water samples ranged from 91.6 mg/l to 97.7 mg/l with a mean value close to 94.1 mg/l according to Table 3 and Figure 7 which were within the acceptable limit of WHO, and WPCSR. Total alkalinity are below the permissible limits of WHO standards according to Table 3. BOD is a factor to evaluate the organic load in a water body. BOD levels, which evaluates the concentration of labile organic matter, demonstrated little spatial or temporal difference according to Table 1 which starting from 2.1 mg/l to 16.1 mg/l in the S1 (average 5.89 mg/l) and 2.56 mg/l-19.3 mg/l in the S2 (average 7.7 mg/l). The maximum value of BOD was recorded in start January 2016 at both S1 and S2 The results in January 2016 shows those waters were unsuitable for drinking according on WPCSR (4 mg/l) due to runoff from farming area at watershed in start the winter season. COD is one of the more utilized aggregate variables in environmental pollution. as mentioned in Table 3 which were within the acceptable limit by Water Pollution Control Statement of Regulation Turkish (WPCSR). The higher limit of COD concentration was in September with 25 mg/l at S2. Increases in COD might be due to an increase in chemical pollutants from runoff of farming area. The samples in Table 1 demonstrated to low variations in averaged ammonia (NH4-N) contents, from 0.027 mg/l to 0.13 mg/l. Nitrate and Nitrite are interconnected, this really is due to contamination by human or animal waste as well as fertilizer run-off [24,29]. The nitrate (NO3-N) value varies from 0.09 to 0.6 mg/l was very low in study area, they fall below the (WHO) which was 10 mg/l NO3-N. Likewise, Nitrite concentration was unimportant and no real pattern was noticed in concentration. Phosphate are chemical substances founded from the elements phosphorous and oxygen, they could be an important for plant and animal growth. Phosphor is actually in waters in some phosphate forms. Dissolved reactive phosphate (orthophosphate PO4-P) is the only phosphate substance that might be used by many plants and organisms [30]. The phosphate values (po4-p) obtained were within permissible limit (0.65 mg/l) for (WPCSR). The lower limit and upper limit values were (0.021 mg/l and 0.08 mg/l) for sites (S1 and S2) respectively, which recommend that phosphorus is not often noticed in high concentrations in waters as it is actually used up by plants.

The water quality index analyses

WQI is created by using the measurement of some important physicochemical variables of the surface water. The values of some physicochemical parameters for the calculation of WQI are presented in Tables 4 and 5. In addition, Table 6 displays in summary of WQI value from (S1, S2) for every two month starting in September 2015 to July 2016 was calculated to be inside range of poor water and good

NUM	Station (S1)					
	Parameters	Standard values	Unit Weight (Wn)	Observed Values	Quality Rating (qn)	Weighted (Wn.qn)
1	EC	1500	0.000078	447	29.8	0.00232
2	pH	6.5-8.5	0.013764	8.6	77.647	1.068
3	Temperature	25	0.00468	11.85	47.4	0.2218
4	Turbidity	5NTU(WHO)	0.0234	3.68	73.6	1.7222
5	T. Hardness	500	0.000234	94.19	18.83	0.0044
6	Alkalinity	120(WPCSR)	0.000975	28.92	24.1	0.0234
7	DO	8 (WPCSR)	0.014625	9.39	78.93	1.1544
8	BOD	4 (WPCSR)	0.02925	5.89	147.25	4.307
9	COD	25 (WPCSR)	0.00468	7.67	30.68	0.1435
10	NH_4-N	0.2 (WPCSR)	0.585	0.085	42.5	24.86
11	NO_3-N	5 (WPCSR)	0.0234	0.34	6.8	0.1591
12	NO_2-N	1 (WHO)	0.117	0.007	0.7	0.0819
13	PO_4-P	0.65 (WPCSR)	0.18	0.062	9.53	1.716
$\sum W_n = 0.998$						
$WQI=\sum_{i=1}^{n} \frac{Wiqi}{\sum Wi} = \frac{35.46}{0.997} = 35.57$ **Poor water quality (B)**						

Table 4: The computation of Water Quality Index of station (S1).

NUM	Station (S2)					
	Parameters	Standard values	Unit Weight (Wn)	Observed Values	Quality Rating (qn)	Weighted (Wn.qn)
1	EC	1500	0.000078	42	29.46	0.00229
2	pH	6.5-8.5	0.013764	8.71	88.647	1.2202
3	Temperature	25	0.00468	11.42	45.68	0.21378
4	Turbidity	5NTU (WHO)	0.0234	3.88	77.6	1.8158
5	T. Hardness	500	0.000234	94.07	18.81	0.0044
6	Alkalinity	120 (WPCSR)	0.000975	29.12	24.26	0.02366
7	DO	8 (WPCSR)	0.014625	9.5	77.27	1.1301
8	BOD	4 (WPCSR)	0.02925	7.72	193	5.645
9	COD	25 (WPCSR)	0.00468	9.92	39.68	0.1857
10	NH_4-N	0.2 (WPCSR)	0.585	0.07	35	20.475
11	NO_3-N	5 (WPCSR)	0.0234	0.33	6.6	0.1544
12	NO_2-N	1 (WHO)	0.117	0.005	0.5	0.0585
13	PO_4-P	0.65 (WPCSR)	0.18	0.05	7.6923	1.3846
$\sum W_n = 0.998$						
$WQI=\sum_{i=1}^{n} \frac{Wi\,qi}{\sum Wi} = \frac{32.31}{0.997} = 32.41$ **Good water quality (B)**						

Table 5: The computation of Water Quality Index of station (S2).

Sample collection times	WQI			
	Station (S1)	Grading	Station (S2)	Grading
September 2015	17.76	A	18.73	A
November 2015	38.27	B	37.56	B
January 2016	**53.93**	**C**	**56.78**	**C**
March 2016	29.54	B	12.27	A
May 2016	27.08	B	30.32	B
July 2016	32.17	B	32.42	B
Mean	35.16	B	32.05	B

Table 6: Shown Calculation of WQI levels from many types of sample collection times and different sampling sites.

water to excellent water. WQI rating during this study displayed significant temporal differences (Figure 15) whereas January 2016 showed high level of deterioration at (S1, S2), this may be due to starting the winter 2016 where high contribution from runoff at downstream areas which increase of deterioration body water in the Dam. Likewise, water quality was strongly affected by agricultural and domestic uses. Therefore, priority should be given to minimizing these pollution sources to maintain or improve water quality in the watershed [31].

Conclusions and Recommendation

The current study was conducted the main source of drinking water for Kastamonu area (Turkey) for measuring quality of surface water. Water Quality index (WQI) was useful tool to obtain the right decision and evaluating water quality. This technique seems to be more systematic and offers comparative assessment of the water quality for different sampling site and different of temporal sampling. The results reveals are

- During this study the average values of WQI for two station (S1, S2) were categorized as good water quality for the human use (35.5, 32.4) respectively for the period from September 2015 to July 2016.
- Generally, there was significant temporal variations in water quality index among poor quality to excellent quality due to in the beginning rainfall at the winter season where runoff operation carried a lot of material such as organic material or other particles.
- The higher pH values were noticed during the march, that may be mainly related to the photosynthesis.
- In January 2016, the large concentration values of Ammonia, Nitrite, Conductivity and BOD were noticed within the acceptable limit of (WHO) and (WPCSR) except the averages of BOD obtained completely exceeded the Turkish standard (WPCSR) and (WHO) due to runoff from farming area at watershed of Karaçomak dam.

In future, evaluation of water quality in Karaçomak dam should be given main priority of using the microbiological parameters with physico-chemical parameters in WQI calculations and to water quality monitoring.

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