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Using Water Quality Index and Other Criteria to Assess Drinking Water in Kastamonu, Turkey

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ABSTRACT

This study aimed to determine Status of Drinking Water in Kastamonu City using Water Quality Index, Ammonia, Iron, Phosphate and Manganese of drinking water quality in kastamonu City-Turkey. For this purpose, Data collection based on the average of 120 of water samples were taken either at station (before treatment), or from station (after treatment) in kastamonu city between (2011-2015). The average concentrations of the Physicochemical Parameters Water in the kastamonu city (before and after treatment) for (ammonia (NH4-N), phosphate (PO4-P), iron (Fe) and magnesium Mn) averaged between (0.0313-0.026. 0.0522-0.0331 ,0.0473-0.0233 ,0.0512-0.0262 mg/l) respectively. Findings display that the physical and chemical quality (NH4-N, PO4-P, Fe and Mn) were considerably below the Turkish Water Pollution Control Regulation (WPCSR) and USEPA standards for drinking water quality in both station. The Water quality index (WQI) is valuable and special ranking to depict the average water quality status. The Water quality index shows that the (before treatment) a higher (WQI) of 31.50 at Good water quality grades as against 17.18 at Excellent water quality grades recorded in (after treatment) in drinking water of kastamonu city the results indicated the Situation of drinking water in kastamonu city was high quality.

استخدام مؤشر جودة المياه ومعايير أخرى لتقييم مياه الشرب في كاستامونو ، تركيا

ادريس امنيسي ميراك ايدن

تهدف هذه الدراسة إلى تحديد حالة مياه الشرب في مدينة كاستامونو بتركيا باستخدام مؤشر جودة المياه (WQI) وبعض معايير جودة المياه الأخرى مثل (الأمونيا والحديد والفوسفات والمنغنيز). لهذا الغرض، تم جمع البيانات بناءً على متوسط 120 عينة من المياه تم أخذها من محطة التوزيع في مدينة كاستامونو (قبل المعالجة) و (بعد المعالجة) بين (2011–2015). فقد أظهرت النتائج متوسط تراكيز المعلمات الفيزيائية والكيميائية للمياه في مدينة كاستامونو (قبل وبعد المعالجة) للأمونيا والحديد والفوسفات والمنغنيز تراوحت بين (0.026–0.0313). (0.0331–0.0522) (0.0233–0.0473) (0.0262–0.0512) ملغم / لتر على التوالي. تظهر النتائج أن جودة المياه لهذه المؤشرات كانت أقل بكثير من معايير جودة المياه التركية (WPCSR) ومعايير جودة المياه لوكالة حماية البيئة الامريكية (USEPA)في كلتا المحطتين. كما يعتبر مؤشر جودة المياه (WQI) ذو قيمة ورتبة متوسطة كتعبير عن حالة جودة المياه بهذا المؤشر. حيث يوضح مؤشر جودة المياه أن (قبل المعالجة) كانت أعلي حيث سجلت 31.50 (WQI) عند تقييم جيد. في المقابل 17.18 في مقياس جودة المياه عند معدل ممتاز في المحطة بعد المعالجة كتقييم لمياه الشرب في مدينة كاستامونو، وأشارت النتائج إلى ان حالة مياه الشرب كانت عالية الجودة بعد المعالجة

INTRODUCTION

Water is necessary for each natural and anthropic activities; it is an important useful resource for photosynthesis, a driver at the back of most life on the earth. Numerous a long time of water quality monitoring have supplied a realistic (though usually improving) appreciation of which chemicals are probably to be present in drinking waters of traditional sources(Association, 2011). Supply of drinking water is essential to the improvement of any country, however when have been deteriorated due to some vital factors like growing population, industrialization and urbanization (Mohsin et al., 2013). For example, Manganese is the second most considerable metal in the earth's crust after iron. However, the presence of manganese in raw water gives one-of-a-kind problems for water treatment authorities because, in contrast to iron, manganese is not oxidized through air at neutral pH and is not removed all through water treatment strategies except a chemical oxidation step is included (Organization, 2004). Further, collection and classification of a massive amount of information leads to difficulties in assessment and illustration of effects alongside with development of positive management strategies for water resources.

The water quality index (WQI) which assesses the suitability of water quality for domestic purposes used to be adopted. It comprises records from a couple of water quality parameters into a mathematical equation that is a numerical apparatus used to change over a lot of water quality data into a single number which implies the water quality level. In fact, creating WQI in a location is an essential function in the planning of land use and water resources management(Saeedi et al., 2010; Wanda et al., 2012). Many researchers have applied water quality index (WQI) for evaluate water quality and monitoring of temporal variations in Gediz River Izmir turkey (Boyacioğlu and Gündoğdu, 2013) While (Dede et al., 2013) was used five different WQI models for the selected parameters to determine the suitability WQI models. In another study, Water Quality index (WQI) used to be useful tool to achieve the right decision and evaluating water quality in Karacomk Dam in Kastamonu.(Imneisi and Aydin, 2016). Hence, water quality index evaluation of water is essential to determine the quality of groundwater and surface water in any rural and urban areas that influences the suitability for drinking, domestic, swimming, irrigation and industrial requirements.

The objective of this study was to comparison the variables and find out the relationships between parameters by applying WQI for Kastamonu city before treatment and after treatment that is understandable by non-technical people. All studies were performed using the datasets obtained from the kastamonu city(DSI) during the observation period of 2011 and 2015.

MATERIALS AND METHODS

Study Area and Sampling Stations.

The study area is the major source of drinking water for the Kastamonu area where can be found (DSI). Table 1. Which show the all datasets for observation in the kastamonu city(DSI) before and after treatment.

Table .1 which show the all datasets for observation in the kastamonu city(DSI).

Information of Sampling site		
Sampling Stations	Station one	Station two
Name of Sampling Stations	(before treatment)	(after treatment)
Duration of study	From 2011 to 2015	every month
The number of samples	60	60

Geographically, the (DSI) is located at latitudes (41°39' 74.91" N), and longitudes (33° 78' 57.09"E) in the Kastamonu city, Turkey, and elevated 887 m above sea level. Sampling Stations were located on the (DSI) kastamonu city that shows in Fig 1.

Fig. 1. Map shows the (DSI) kastamonu city.

Methodology of calculation water quality index to drinking water in kastamonu city.

The calculation of the WQI was finished utilizing weighted arithmetic water quality index which was principally proposed by Horton (1965) and improved by Brown *et a.*, (1972). The weighted arithmetic index procedure(Brown et al., 1972)) used for the computing WQI of the water body in following advances:

$$\boldsymbol{WQI} = \sum_{\boldsymbol{i=1}}^{\boldsymbol{n}} \frac{\boldsymbol{Wi\ qi}}{\boldsymbol{\sum Wi}} \qquad \textbf{equation (1)}$$

qi: Quality rating for the ith water quality parameters wi: unit weight for the ith parameters.

Firstly, Computation of sub-index of quality rating (qi).

According to Brown *et al.*, (1972), quality rating or sub-index (qi) was calculated using the following expression

$$\boldsymbol{qi} = \left(\frac{(\boldsymbol{Va} - \boldsymbol{Vi})}{(\boldsymbol{Vs} - \boldsymbol{Vi})}\right)\boldsymbol{100} \qquad \textbf{equation (2)}$$

qi: Quality rating for the ith water quality parameters

Va: Actual value present of the (ith) parameter at a given sampling station Vi: Ideal value (0 for all parameters accepts pH which are 7.0 pH).

Vs: Standard value

If quality rating = zero that means the complete absence of pollutants. while, quality rating $o<qi<100$ implies that, the pollutants are above the standards(Ahmad, 2014).

Secondly, Computation of unit weight (relative weight calculation)

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

$$\boldsymbol{w_i} = \frac{\boldsymbol{k}}{\boldsymbol{si}} \qquad \textbf{equation(3)}$$

w_i: $unit\ weight\ for\ the\ \mathrm{i}^{th}\ parameter.$

s_i: standards value $for\ the\ \mathrm{i}^{th}\ parameter.$

k: Relative constant, this value considered (1)here, also can calculate using the following equation:

$$\boldsymbol{k} = \frac{\boldsymbol{1}}{\sum\left[\frac{\boldsymbol{1}}{\boldsymbol{si}}\right]} \quad \textbf{equation} \quad (4)$$

In brief, the rating of water quality according to this WQI is given in table 2. (Chatterjee and Raziuddin, 2002; Asuquo and Etim, 2012)

Table 2. Water quality rating as per weighted arithmetic water quality index.

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

The chemical analysis.

The major water quality constituents include water temperature, pH, EC, Turbidity, Chloride (Cl), ammonium (NH4-N), nitrate (NO3-N), nitrite (NO2-N), phosphate (PO4-P), Iron (Fe), Sulfate (SO4), and Manganese (Mn). The results of the drinking water of kastamonu city analysis were assessed to check if they satisfy the permissible limits of water quality parameters given in Turkish Water Pollution Control Regulation and USEPA standards for drinking water quality. The standard values are also given in table 3 and 4 (TSE 2005; EPA 2009; WHO 2009, 2011a, 2011b; Turkish-Regulation 2012).

Table 3. Average the Physicochemical Parameters Water in the kastamonu city before treatment from 2011 to 2015.

Before treatment						
Par-ameters	Sta-ndard	2011	2012	2013	2014	2015
EC	1500	-	-	436.3	-	-
pH	8.5	7.99	8.11	7.943	8.16	8.01
Tem	25	18.84	18.53	18.53	18.13	13.19
Turb	5	2.5342	3.266	3.966	3.61	3.89
Cl	120	3.65	3.666	3.641	3.44	3.408
NH4	0.2	0.02	0.04	0.043	0.025	.0283
NO3	5	0.088	0.116	0.077	0.008	.0100
NO2	1	0.003	0.004	0.004	0.003	.0045
PO4-P	0.65	0.048	0.067	0.041	0.036	.0667
SO4	200	24.66	23.08	23.58	22.66	21.04
Fe	0.3	0.0317	0.038	0.055	0.068	.0425
Mn	0.1	0.044	0.051	0.056	0.049	0.055

Table 4. Average the Physicochemical Parameters Water in the kastamonu city after treatment from 2011 to 2015.

After treatment						
Par-ameters	Stan-dard	2011	2012	2013	2014	2015
EC	1500	-	-	438.9	-	-
pH	8.5	8.03	8.04	7.97	8.03	7.92
Tem	25	17.8	19.0	18.53	18.2	13.08
Turb	5	0.42	0.47	0.54	0.65	0.62
Chloride	120	4.24	5.14	3.64	4.93	4.89
(Cl)	0.2	0.001	0.04	0.04	0.03	0.004
(NH4-N)	5	0.11	0.10	0.067	0.005	0.008
(NO3-N)	1	0.003	0.003	0.003	0.00	0.007
(NO2-N)	0.65	0.03	0.03	0.03	0.03	0.034
(PO4-P)	200	24.4	24	23.5	24.5	22.36
(SO4)	0.3	0.03	0.01	0.02	0.02	0.02
Iron	0.1	0.02	0.02	0.035	0.02	0.028

Results and Discussion

The Physical-Chemical Characteristics of Water in the kastamonu city (before and after treatment) from 2011 to 2015. The statistical computations were made by SPSS 19.0. The general statistics determined for the drinking water quality are summarized in Table 5 and 6. which submit the min value, max value, mean, and standard deviation of the results for each of the 12 variables.

The mean of EC values for the kastamonu city through 2011 to 2015 periods ranged from (402 to 495 µS/cm) at before and after treatment stations. Table 3 and 4. which usually were lower than the recommended level (1500 µS/cm) by (WPCSR) (amendment table 1: RG-13/2 / 2008-26786) and WHO (WHO, 2011b).

Table 5. Statistics of Physiochemical variables (all in mg/l and EC in µS/cm) in the kastamonu city (before treatment) between (2011-2015).

Descriptive Statistics the Physical-Chemical Characteristics of Water in the kastamonu city before treatment between (2011-2015)					
Par-ameters	N	Min	Max	Mean	Std. Dev
pH	12	402.0	486.0	436.33	33.937
Tem	60	7.49	8.62	8.04	.23337
Turb	60	8.70	20.00	17.44	2.734
(Cl)	60	.82	10.60	3.45	1.915
(NH_4-N)	60	2.70	4.70	3.561	.462
(NO3-N)	60	.00	.09	.0313	.0227
(NO2-N)	60	.00	.50	.0602	.0808
(PO_4-P)	60	.00	.02	.0043	.0024
(SO4)	60	.01	.23	.0522	.0372
(Fe)	60	19.00	27.00	23.0	2.116
Mn	60	.01	.17	.0473	.0311

Table 6. Statistics of Physiochemical variables (all in mg/l and EC in µS/cm) in the kastamonu city (after treatment) between (2011-2015).

Descriptive Statistics the Physical-Chemical Characteristics of Water in after treatment at kastamonu city between (2011-2015)					
Par-ameters	N	Min	Max	Mean	Std. Dev
pH	12	404.00	495.00	438.98	34.991
Tem	60	7.70	8.32	8.0012	.128
Turb	60	5.00	20.30	17.35	3.284
(Cl)	60	.20	1.16	.5437	.189
(NH_4-N)	60	2.90	6.70	4.57	.800
(NO_3-N)	60	.00	.08	.0260	.0267
(NO_2-N)	60	.00	.50	.0600	.0861
(PO_4-P)	60	.00	.05	.0040	.0064
(SO_4)	60	.00	.11	.0331	.0177
(Fe)	60	20.00	27.00	23.7733	1.580
Mn	60	.01	.20	.0233	.0264

The results demonstrated those waters were suitable for drinking according to on world health organization (1500 µS/cm) (WHO, 2011b). The pH of the drinking water of kastamonu city was within a range of 7.49-8.62 pH. While, temperature mixed from 17.44 C in station (before treatment) to 17.35 C in station (after treatment), displaying the likely regular pattern with no differences between the sampling stations. The turbidity of water in Table 5 and 6 at kastamonu city displays that turbidity was higher with 3.34 NTU at station

(before treatment) Whereas station (after treatment) was lower with 0.54 NTU. 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(Imneisi and Aydin, 2016)

A comparative study using The major variation of NH4-N, Fe, PO4-P and Mn.

Table 3 and 4 show that total ammonia levels (NH4-N) were also noticed in all samples (n=120) and ranged from .00 to .09 mg/l. no significant spatial differences were observed. While, phosphate levels fluctuated between before and after 0.0/0.05 to 0,0/ 0.03 mg/l with an average of 0.0 / 0.03 mg/l, respectively in kastamonu city. A high phosphate was observed in station before treatment. While The minimum and maximum value of iron (Fe) in before and after treatment 0.01/0.017 to 0.01/0.02 mg/l with an average of 0.047/0.023 mg/l, respectively in kastamonu city. Ammonia, phosphate and iron levels in the drinking water samples were noticed within the acceptable limit of these values for ammonia, phosphate and iron are below the (WPCSR) (Amendment Table 1: RG-13/2 / 2008-26786) and WHO in both station (WHO, 2011a).

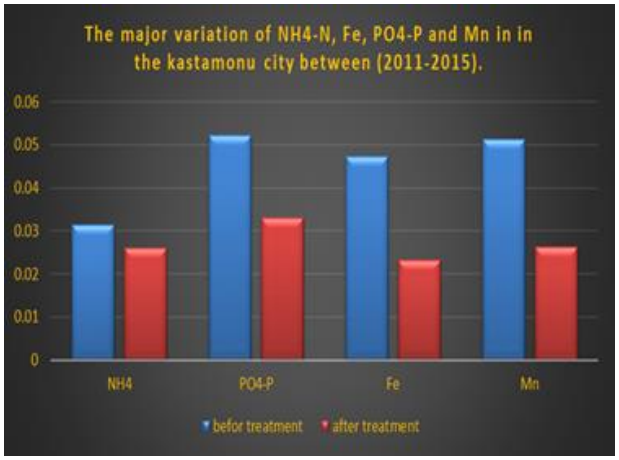

Fig 2. The major variation of NH4-N, Fe, PO4-P and Mn in in the kastamonu city between (2011-2015).

The levels of manganese in the drinking water at the two station (before and after treatment) are shown in Fig. 2. manganese level was at the 0.054- and .0262-mg/liter level respectively. These values are below the (WPCSR) (Amendment Table 1: RG-13/2 / 2008-26786) and WHO in both station (WHO, 2011a)

A comparative study using Water Quality Index (WQI).

Water Quality Index(WQI) in Stations drinking water of kastamonu city (before treatment and after treatment) between (2011-2015). The WQI used to be calculated by the use of the requirements of drinking water quality recommended by way of the World Health Organization (WHO) and Water Pollution Control Statement of Regulation Turkish (WPCSR) (Amendment Table 1: RG-13/2 / 2008-26786). WQI is a beneficial method in evaluating the suitability of water for a number positive uses. The WQI values of the determined investigation from different sampling stations (before and after treatment) are given in Table 7, and 8.

Table 7. The Water Quality Index in the kastamonu city (before treatment) based on average of Physiochemical variables between (2011-2015).

The Water Quality Index in the kastamonu city (before treatment) based on average of Physiochemical variables between (2011-2015).

Par-ameter	Standard values	Observed Values	Unit Weight (Wn)	Quality Rating (qn)	Weighted (Wn. qn)
pH	1500	436.333	0.000031	29.08	0.00058
Tem	8.5	8.0465	0.005482	22.29	0.0786
Turb	25	17.4467	0.001864	69.78	0.08374
(Cl)	5	3.4557	0.00932	69.11	0.4146
NH_4-N)	120	3.5617	0.000388	2.96	0.0007
NO_3-N)	0.2	0.0313	0.233	15.66	2.3475
(NO_2-N)	5	0.0602	0.00932	1.20	0.0072
(PO_4-P)	1	0.0043	0.0466	0.42	0.012
(SO_4)	0.65	0.0522	0.07169	8.02	0.37065
Fe	200	23.0083	0.000233	11.50	0.00172
Mn	0.3	0.0472	0.155333	15.75	0.015
				31.47	
$WQI = \sum_{i=}^{n}$				WQI = 31.50	

Table 8. The Water Quality Index in the kastamonu city (after treatment) based on average of Physiochemical variables between (2011-2015).

The Water Quality Index in the kastamonu city (after treatment) based on average of Physiochemical variables between (2011-2015)					
Par-ameters	Standard values	Observed Values	Unit Weight (Wn)	Quality Rating (qn)	Weighted (Wn. qn)
pH	1500	438.98	0.000031	29.265	0.00058
Tem	8.5	8.00	0.00548	17.76	0.06228
Turb	25	17.3	0.001864	69.43	0.08304
(Cl)	5	.5437	0.00932	10.87	0.0652
(NH_4-N)	120	4.57	0.00038	3.80	0.00095
(NO_3-N)	0.2	.0260	0.233	13	1.95
(NO_2-N)	5	.0600	0.00932	1.2	0.0072
(PO_4-P)	1	.0040	0.0466	0.403	0.012
(SO_4)	0.65	.0331	0.07169	5.08	0.2350
(Fe)	200	23.7	0.00023	11.88	0.00177
Mn	0.3	.0233	0.155	7.75	0.015
				17.17	
$WQI = \sum_{i=1}^{n} \frac{Wi\ qi}{\sum Wi}$				WQI = 17.18	

Figure 3. shows the Situation of drinking water in kastamonu city was high quality and was much better at station (after treatment) when utilizing water quality index (WQI).

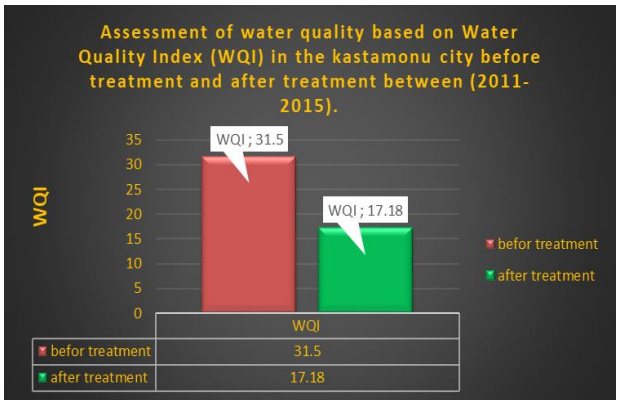

Figure 3. The Comparison of WQI in Stations drinking water of kastamonu city (before treatment and after treatment) between (2011-2015).

CONCLUSION

During this paper, the technique water quality index was successfully applied to evaluate water quality and determine the role in Kastamonu, Turkey. Then, the conclusions based totally on the analyses carried out in this study are:

- There is variation in the physiochemical indicator in the parameters evaluated between two station (before and after treatment).
- The mean of Turbidity (NTU) for the kastamonu city through 2011 to 2015 periods were observed 3.34 (before treatment) and 0.54 (after treatment) that is reflected the level of treatment in drinking water of kastamonu city.
- The average concentrations of the Physicochemical Parameters Water in the kastamonu city (before and after treatment) for (NH4-N, PO4-P, Fe, and Mn) averaged between (0.0313-0.026. 0.0522-0.0331 ,0.0473-0.0233 ,0.0512-0.0262 mg/l) respectively.
- Findings reveal that the physical and chemical quality (NH4-N, PO4-P, Fe, and Mn) were considerably below the (WPCSR) (Amendment Table 1: RG-13/2 / 2008-26786) and WHO in both station.
- Water quality index (WQI) is valuable and special ranking to depict the average water quality status.
- Drinking water (after treatment) has made it possible to treat and control of manganese level. Manganese level has been under control for a 5 -year period and has resulted in the production of high water quality.
- The Situation of drinking water in kastamonu city was high quality and was much better at station (after treatment) when utilizing water quality index (WQI).
- The average water quality index (after treatment) in kastamonu city is Excellent water quality.

The Water quality index shows that the (before treatment) a higher (WQI) of 31.50 at Good water quality grades as against 17.18 at Excellent water quality grades recorded in (after treatment) in drinking water of kastamonu city the results indicated the Situation of drinking water in kastamonu city was high quality.

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