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ORIGINAL PAPER

A preliminary correlation and regression study on drinking water quality of Suşehri district in Turkey

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Abstract

The correlation and regression study deals with the drinking water quality of Suşehri located at Central Anatolian region of Turkey. Over the period between May 2013 and June 2014, twelve field surveys were conducted and water samples were collected from four different stations in Suşehri. In the collected water samples, totally fourteen physicochemical parameters were analyzed. Physicochemical parameters studied were in varying ranges such as water temperature 14.00-20.60 ^{0}C, dissolved oxygen 3.80-6.50 mg/l, BOD_5 0.50-1.60 mg/l, pH 7.00-8.00, ammonium 0.00-0.16 mg/l, nitrite 0.00-0.25 mg/l, nitrate 0.00-2.30 mg/l, orto-phosphate 0.00-0.25 mg/l, chloride 4.00-12.00 mg/l, carbonate hardness 2.20-8.20 ^{0}dH, acid binding capability 0.80-3.00 mmol/l, total hardness 2.60-9.20 ^{0}dH, calcium 18.56-65.69 mg/l and magnesium 11.13-39.38 mg/l in Suşehri. Highly positive correlation coefficient is observed between carbonate hardness and acid binding capability ($R=0.975^{**}$), carbonate hardness and total hardness ($R=0.891^{**}$), carbonate hardness and calcium ($R=0.899^{**}$), carbonate hardness and magnesium ($R=0.892^{**}$), acid binding capability and total hardness ($R=0.892^{**}$), acid binding capability and calcium ($R=0.899^{**}$), acid binding capability and magnesium ($R=0.893^{**}$), total hardness and calcium ($R=0.996^{**}$), total hardness and magnesium ($R=1.000^{**}$), calcium and magnesium ($R=0.996^{**}$). The correlation and regression study showed significant linear relationship among different pairs of water quality parameters in Suşehri. Based on the data recorded, all of the physicochemical parameters are well within the permissible limits as per standards. The quality of water is safe for drinking purposes in Suşehri.

Keywords: Drinking Water Quality, Correlation, Regression, Suşehri, Turkey.

1. Introduction

All biological organisms depend on water to carry out complex biochemical processes which aid in the sustenance of life on earth. Over 70 per cent of the earth's surface materials consists of water and apart from the air man breathes, water is one of the most important elements to man. The quality of water is of great importance also for human lives as it is commonly consumed and used by households (M.S. HOLT [1]; F.X.R. VAN LEEUWEN [2]; L. PETRACCIA & al. [3]; V.V. GONCHARUK [4]). Water use has been growing at more than twice the rate of population growth in the last century. Research suggests that the world population could peak at 9 billion by 2070. This level of population growth will result in increased demand for potential drinking water from agricultural, industrial and domestic sectors of the economy. Safe drinking water is drawn from freshwater sources, which represent only 2.5% of the 1.4 billion cubic kilometers of water covering the earth. Less than 1% of this fresh water is safe to drink without prior treatment. Economic growth seems to be dependent on high levels of access to safe drinking water. Access to safe drinking water is already beginning to decline in the emerging markets due to growing demand for supplies of an increasingly scarce resource. Furthermore, the quality of drinking water is in decline in many parts of the world, and increasing socioeconomic barriers, such as rising water prices, mean that fewer people have access to safe drinking water (J. FOGDEN [5]).

Annual consumption of drinking water was almost 74 cubic metres per capita when the Europe average was about 100 cubic metres. Water consumption increased eight percent between 1980 and 1997. Among rural residents, sixty-two percent of have access to safe drinking water and nearly seventy percent of the urban population is connected to safe drinking water. It is significant that fifty percent of the total drinking water potential is lost in the supply networks. The population of Turkey is expected to reach 87 million in 2020 and the total capacity of consumable water resources per capita is foreseen as 1,042 cubic metres per year (K. OKUMUS [6]; H. DUZEN & H.M. OZLER [7]). Suşehri is a district in Central Anatolian region of Turkey. To the best of our knowledge, has not been directly studied concerning the water quality physicochemical parameters, correlations and regression between them in drinking water samples collected from Suşehri district. This correlation and regression study deals with the drinking water quality of Suşehri.

2. Materials and Methods

2.1. Study area

The study area is Suşehri located at 40º10' N - 38º06' E in Central Anatolian region of Turkey. Suşehri is situated in the east of Sivas about 140 km the city centre and located in altitude of 1163 m average above sea level. The area of Suşehri, which is a district of Sivas in terms of administration and is about 985 square kilometers. In 2011 data show that the average quantity of water consumption per inhabitant is about 82 litres per a day (ILBANK [8]). Suşehri, a district of about 15135 inhabitants according to Turkish Statistical Institute address based population registration system results in 2014. In the district which has been named as Suşehri because of the bounty of water in the region.

2.2. Experimental practices

The drinking water samples were collected from different four tap water stations monthly in Suşehri namely; Öksülü (station-I), Yeni (station-II), Köroğlu (station-III) and Yalnızbağlar (station-IV) between May 2013 and June 2014. The water samples were analyzed for fourteen parameters to determine the drinking water quality with respect to water temperature, dissolved oxygen, biochemical oxygen demand (BOD_5), pH, ammonium, nitrite, nitrate, orto-phosphate, chloride, carbonate hardness, acid binding capability, total hardness, calcium and magnesium. The water temperature of each sample was measured and recorded using a thermometer calibrated in degree Celsius. Dissolved oxygen and BOD_5 were measured with 1.11107.0001 test kit as titrimetric method. The pH, ammonium, nitrite, nitrate and orto-phosphate were measured by colorimetric method using Aquamerck test kits 1.08027.0001, 1.08024.0001, 1.08025.0001, 1.11170.0001 and 1.14661.0001 respectively. Chloride, carbonate hardness-acid binding capability and total hardness were measured by titrimetric method using Aquamerck test kits 1.11106.0001, 1.08048.0001 and 1.08039.0001 respectively. Calcium and magnesium values were calculated according to the formula of total hardness change (K. HOLL [9]; S. DIRICAN & M. BARLAS [10]).

2.3. Data comparisons and statistical analyses

The results were compared against drinking water quality standards laid by World Health Organization, WHO [11]; European Communities Drinking Water Directive 98/83/EC, ECDWD [12]; Turkish Waters Regulation for Human Consumption, TWRHC [13]; United States Environmental Protection Agency National Primary Drinking Water Regulations, USEPA [14] and Australian Drinking Water Guidelines, ADWG [15]. Range, skewness, kurtosis, median, mean, standard deviation, correlation and regression were calculated using SPSS for windows version 17.5 statistical software was used for all data analysis.

3. Results and Discussion

The minimum, maximum, range, skewness, kurtosis, median, mean and standard deviation values generated from the analysis of the water samples are presented in Table 1. The water sample temperatures ranged from 14.00 to 20.60 ^{0}C with station-III having the highest temperature while station-III and station-IV have the lowest. The range and median values of the water temperature of all water samples are 6.60 and 16.00 ^{0}C, respectively. In this study period, the mean value of water temperature with standard deviation was 16.31±1.59 ^{0}C (Table 1). Temperature values are known to be dependent on the climatic condition at a particular geographical area and period. The concentration of the dissolved oxygen was lowest in station-I (3.80 mg/l) and highest in station-III (6.50 mg/l). The range and median values of the dissolved oxygen of all water samples are 2.70 mg/l and 5.15 mg/l, respectively. The mean value of dissolved oxygen with standard deviation was 5.18±0.67 mg/l (Table 1). The concentration of BOD_5 was lowest in station-I and station-II (0.50 mg/l) and highest in station-IV (1.60 mg/l). The mean value of BOD_5 with standard deviation was 0.88±0.27 mg/l (Table 1). The BOD_5 values of all the water samples under the 5.0 O_2 mg/l permissible limit recommended by TWRHC [13] for drinking water.

Table 1. Descriptive statistics of physicochemical water quality parameters in Suşehri.

Parameters	Units	N	Min.	Max.	Range	Skewness	Kurtosis	Median	Mean	SD±
WT	^{0}C	48	14.00	20.60	6.60	0.72	0.16	16.00	16.31	1.59
DO	mg/l	48	3.80	6.50	2.70	0.20	-0.64	5.15	5.18	0.67
BOD_5	mg/l	48	0.50	1.60	1.10	0.65	-0.15	0.80	0.88	0.27
pH	-	48	7.00	8.00	1.00	0.28	-0.60	7.50	7.65	0.25
Ammonium	mg/l	48	0.00	0.16	0.16	1.33	-0.24	0.00	0.04	0.07
Nitrite	mg/l	48	0.00	0.25	0.25	6.93	48.00	0.00	0.01	0.04
Nitrate	mg/l	48	0.00	2.30	2.30	0.78	-1.29	0.00	0.74	1.02
OP	mg/l	48	0.00	0.25	0.25	-0.44	-1.89	0.25	0.15	0.12
Chloride	mg/l	48	4.00	12.00	8.00	-0.02	-0.21	8.00	7.52	1.83
CH	^{0}dH	48	2.20	8.20	6.00	-0.04	-0.27	5.00	5.15	1.44
ABC	mmol/l	48	0.80	3.00	2.20	0.04	-0.57	1.80	1.85	0.55
TH	^{0}dH	48	2.60	9.20	6.60	-0.36	0.08	6.30	6.33	1.55
Calcium	mg/l	48	18.56	65.69	47.13	-0.33	-0.04	44.99	44.98	11.10
Magnesium	mg/l	48	11.13	39.38	28.25	-0.37	0.07	26.97	27.07	6.60

WT: Water Temperature, DO: Dissolved Oxygen, BOD_5: Biochemical Oxygen Demand, OP: Orto-Phosphate, CH: Carbonate Hardness, ABC: Acid Binding Capability, TH: Total Hardness, N: Number of Observations, Min: Minimum, Max: Maximum, SD: Standard Deviation in the table.

The value of pH ranged from 7.00 to 8.00 with station-I, station-II, station-III and station-IV have the highest pH while station-III having the lowest. The mean value of pH with standard deviation was 7.65±0.25 (Table 1). The pH values fall within the (>6.5 to <9.5) ECDWD [12], the (>6.5 to <9.5) TWRHC [13], the (6.5 to 8.5) USEPA [14], the (6.5 to 8.5) WHO [11] and the (6.5 to 8.5) ADWG [15] the permissible limits for drinking water.

The results of ammonium analysis in the water samples varied from 0.00 to 0.16 mg/l. The mean value of ammonium with standard deviation was 0.04±0.07 mg/l (Table 1). The ammonium levels are limited under the 0.50 NH_4–N mg/l recommended by ECDWD [12] and TWRHC [13] for drinking water. The value of nitrite ranged from 0.00 to 0.25 mg/l with station-IV having the highest nitrite while station-I, station-II, station-III and station-IV have the lowest. The mean value of nitrite with standard deviation was 0.01±0.04 mg/l (Table 1). The nitrite levels are limited under the 0.50 NO_2–N mg/l recommended by ECDWD [12] and TWRHC [13] for drinking water. The nitrite values of all the water samples under the 1 NO_2–N mg/l permissible limit recommended by USEPA [14] for drinking water. The results of nitrate analysis in the samples varied from 0.00 to 2.30 mg/l. The mean value of nitrate with standard deviation was 0.74±1.02 mg/l (Table 1). The nitrate values of all the water samples under the 10 NO_3–N mg/l permissible limit recommended by USEPA [14] for nitrate. The nitrate levels are limited under the 50 NO_3–N mg/l recommended by ECDWD [12], TWRHC [13] and WHO [11] for drinking water.

The value of chloride was found in the range of 4.00 to 12.00 mg/l in Suşehri. The maximum value (12.00 mg/l) was found in the station-IV and minimum value (4.00 mg/l) found in the station-I and station-II. The mean value of chloride with standard deviation was 7.52±1.83 mg/l (Table 1). The chloride values are below the 250 Cl^- mg/l recommended by ECDWD [12], TWRHC [13], USEPA [14] , WHO [11] and ADWG [15] for chloride.

The value of total hardness ranged from 2.60 to 9.20 ^{0}dH in German degrees with station-IV having the highest total hardness while station-I having the lowest. The mean value of total hardness with standard deviation was 6.33±1.55 ^{0}dH (Table 1). In present study term German degrees were used to describe water hardness (German degree 1 °dH= 17.85 mg/l $CaCO_3$). According to this change equation, the value of total hardness ranged from 46.41 to 164.22 mg/l $CaCO_3$ in Suşehri. This phenomenon according to ADWG [15], degrees of hardness can be described as follows; <60 mg/l $CaCO_3$ soft but possibly corrosive, 60-200 mg/l $CaCO_3$ good quality, 200-500 mg/l $CaCO_3$ increasing scaling problems, >500 mg/l $CaCO_3$ severe scaling. According to those limits, the drinking water is soft but possibly corrosive (46.41 mg/l $CaCO_3$) and good quality (164.22 mg/l $CaCO_3$) in Suşehri. The 1984 World Health Organization Guidelines value for total hardness is 500 mg/l. The 1993 WHO Guidelines do not provide a specific value for hardness. No limit is suggested from the 2011 WHO Guidelines for hardness. The 2013 Australian Drinking Water Guideline suggests total hardness (as calcium carbonate) levels in drinking water should not exceed 200 mg/l. In Suşehri, the total hardness values of all the tap water samples under the 200 mg/l permissible level recommended by ADWG [15] for drinking water.

The value of calcium was found in the range of 18.56 to 65.69 mg/l. The maximum value (65.69 mg/l) was found in the station-IV and minimum value (18.56 mg/l) found in the station-I. The mean value of calcium with standard deviation was 44.98±11.10 mg/l (Table 1). No limit is suggested from the 2005 Turkish Waters Regulation for Human Consumption for calcium. The 2001 Turkish Waters Regulation for Human Consumption suggests calcium levels in drinking water should not exceed 100 mg/l. According to this limit, the calcium values are below the 100 Ca^{+2} mg/l in Suşehri.

The value of magnesium was found in the range of 11.13 to 39.38 mg/l. The maximum value (39.38 mg/l) was found in the station-IV and minimum value (11.13) found in the station-I. The mean value of magnesium with standard deviation was 27.07±6.60 mg/l (Table 1). Similarly, no limit is suggested from the 2005 Turkish Waters Regulation for Human Consumption for magnesium. The 2001 Turkish Waters Regulation for Human Consumption suggests magnesium levels in drinking water should not exceed 50 mg/l. According to the limit, the magnesium values are below the 50 Mg^{+2} mg/l in Suşehri for drinking water.

Correlation analysis shows the intensity of dependence between studied traits (N. DJURIC & al. [16]). Pearson correlation analysis was used to determine the relationship between the variables in the study. The numerical values of correlation coefficient, R for the fourteen drinking water quality parameters are presented in Table 2. Highly positive correlation coefficient is observed between carbonate hardness and acid binding capability (R=0.975**), carbonate hardness and total hardness (R=0.891**), carbonate hardness and calcium (R=0.899**), carbonate hardness and magnesium (R=0.892**), acid binding capability and total hardness (R=0.892**), acid binding capability and calcium (R=0.899**), acid binding capability and magnesium (R=0.893**), total hardness and calcium (R=0.996**), total hardness and magnesium (R=1.000**), calcium and magnesium (R=0.996**). However some very poor correlation were observed between nitrite and carbonate hardness (R=0.312*) so that nitrite is weakly depend on carbonate hardness while low correlation observed between nitrite and acid binding capability (R=0.307*). Similarly, very poor correlation were observed between BOD_5 and carbonate hardness (R=0.361*) so that BOD_5 is weakly depend on carbonate hardness while low correlation observed between BOD_5 and acid binding capability (R=0.313*). Very poor negative correlation is observed between water temperature and ammonium (R=-0.357*), between dissolved oxygen and pH (R=-0.309*), between dissolved oxygen and orto-phosphate (R=-0.337*). The dissolved oxygen shows a negative correlation with pH and orto-phosphate. A medium and positive correlation is found between ammonium and orto-phosphate (R=0.441**), BOD_5 and chloride (R=0.413**), BOD_5 and total hardness (R=0.494**), BOD_5 and calcium (R=0.494**), BOD_5 and magnesium (R=0.493**).

Table 2. Pearson correlation coefficients among the drinking water quality parameters in Suşehri.

Parameters	WT	DO	BOD_5	pH	Ammonium	Nitrite	Nitrate	OP	Chloride	CH	ABC	TH	Calcium	Magnesium
WT	1													
DO	0.15	1												
BOD_5	0.12	0.19	1											
pH	-0.08	-0.309*	0.11	1										
Ammonium	-0.357*	-0.06	-0.01	-0.02	1									
Nitrite	0.04	0.22	-0.15	-0.09	-0.08	1								
Nitrate	0.14	-0.06	-0.22	-0.19	0.389**	0.06	1							
OP	-0.24	-0.337*	0.10	0.00	0.441**	-0.18	0.16	1						
Chloride	0.19	0.392**	0.413**	-0.13	-0.07	0.20	-0.11	-0.24	1					
CH	0.421**	0.27	0.361*	0.05	-0.22	0.312*	0.04	-0.10	0.575**	1				
ABC	0.424**	0.26	0.313*	0.04	-0.27	0.307*	0.00	-0.11	0.547**	0.975**	1			
TH	0.446**	0.18	0.494**	0.09	-0.18	0.20	-0.03	-0.02	0.489**	0.891**	0.892**	1		
Calcium	0.454**	0.19	0.482**	0.09	-0.17	0.20	-0.02	-0.03	0.486**	0.899**	0.899**	0.996**	1	
Magnesium	0.446**	0.17	0.493**	0.09	-0.18	0.20	-0.03	-0.02	0.491**	0.892**	0.893**	1.000**	0.996**	1

WT: Water Temperature, DO: Dissolved Oxygen, BOD_5: Biochemical Oxygen Demand, OP: Orto-Phosphate, CH: Carbonate Hardness, ABC: Acid Binding Capability, TH: Total Hardness, N= 48, *, Significant at the 0.05 level ($p<0.05$), **, Significant at the 0.01 level ($p<0.01$).

Similarly, the relationship between water temperature with carbonate hardness, acid binding capability, total hardness, calcium and magnesium is established which give correlation coefficient $R=0.421^{**}$, $R=0.424^{**}$, $R=0.446^{**}$, $R=0.454^{**}$ and $R=0.446^{**}$ respectively, showing a medium and positive correlation (Table 2). The correlation and regression study showed significant linear relationship among different pairs of water quality parameters. The chloride shows medium and positive correlation with calcium and magnesium. Occurrence of medium correlation between calcium and magnesium indicates about the total hardness of the Suşehri drinking water. In the study, it is evident that distribution of carbonate hardness, acid binding capability, total hardness, calcium and magnesium were significantly correlated (R>0.8) in Suşehri. The ammonium is positively correlated with orto-phosphate (0.441), but the orto-phosphate is negatively correlated with dissolved oxygen (-0.337). The total hardness is positively correlated with calcium (0.996) in the study. Similar type of positive correlation was observed between total hardness and calcium (0.953) in Coimbatore district, India (K. JOTHIVENKATACHALAM & al. [17]).

The calculation of correlation coefficient between water quality variables and regression analysis provide indirect means for rapid monitoring of water quality (N. KUMAR & D.K. SINHA [18]). Similar, regression equations have been applied in other parts of the world to predict the level of significance of water quality variables. The different depended parameters of water quality were calculated using the regression equation and by substitutions. Hierarchical stepwise multiple linear regression models were used for the regression equations in the study. The regression equations obtained from the analysis are presented in Table 3. The regression analysis carried out to relate nitrate, pH, chloride, total hardness, calcium and magnesium in Suşehri. A linear relationship was established for these parameters for the study area.

Table 3. Regression equations for some drinking water quality parameters in Suşehri.

N	R Value	Regression Equation (Y= a + bX)
48	R= 0.489	Nitrate= -2.833(7.541*Ammonium)+(0.202*WT)
48	R= 0.309	pH= 8.250(-0.117*DO)
48	R= 0.626	Chloride= 0.573(0.643*CH)+(0 .702*DO)
48	R= 1.000	TH= -0.014(0.236*Magnesium)+(-0.008*CH)
48	R= 0.996	Calcium= -0.302(1.673*Magnesium)
48	R= 1.000	Magnesium= 0.063(4.239*TH)+(0.036*CH)

N: Number of Observations, R: Multiple Linear Correlation Coefficient, WT: Water Temperature, DO: Dissolved Oxygen; CH: Carbonate Hardness, TH: Total Hardness, Stepwise (Criteria: Probability of F to enter <= 0.050, Probability of F to remove >= 0.100).

The multiple linear regression models were generated for the most correlated parameters that had the same correlation during study period. The prediction of total hardness from selected parameters was fairly good. The independent variables such as magnesium and carbonate hardness were significant in predicting total hardness value (R=1.000) in the study. The total hardness could be ascribed to the combined effect of magnesium and carbonate hardness. Similarly, the prediction of magnesium from selected parameters was fairly good. The independent variables such as total hardness and carbonate hardness were significant in predicting magnesium value (R=1.000). The magnesium could be ascribed to the combined effect of total hardness and carbonate hardness. The prediction of calcium from selected parameters was fairly good. The independent variable such as magnesium was significant in predicting calcium value (R=0.996). The calcium could be ascribed to the combined effect of magnesium (Table 3). Regression equation can be widely used for establishing some good correlations between physicochemical water parameters and these equations can be used to predict in Suşehri.

In the study, we have established six good correlations and derived six different regression equations. The detailed statistical study on drinking water quality reveals that magnesium and carbonate hardness show a very good correlation with total hardness. Thus the regression equation formed from the study can be used to find the approximate value of these two drinking water qualities by using total hardness. The multiple linear regression equations demonstrated the cause and effect relationship between water quality parameters at multiple scales, which is an important factor for the maintenance of Suşehri drinking water quality. The results of analysis can be used to develop predictive models for the drinking water quality. All of these are worthy of further research in the study area.

4. Conclusion

This study provides new information on the levels of physicochemical parameters for drinking water quality from Suşehri district in Turkey. The statistical assessment is also carried out for the physicochemical parameters. All the physicochemical parameters recorded were within acceptable limits in the study area. The quality of water is safe for drinking purposes in Suşehri. The correlation and regression study showed significant linear relationship among different pairs of water quality parameters in Suşehri. These results can therefore serve as baseline data for Suşehri drinking water quality and for comparisons with future studies. This study will help drinking water quality conservation in Suşehri. It is the basic duty of every individual to conserve water resources. To protect drinking water quality in Suşehri, it should be monitored regularly.

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