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Quantitative Analysis of Tap Water and Commercial Water Hardness Using Lime Soda Method

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Contents

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ABSTRACT

Water hardness is important to fish culture and is a commonly reported to be an aspect of water quality. It is a measure of the quantity of divalent ions such as calcium, magnesium and/or iron in water. [1] The present study aimed to answer the question "*Do tap water and commercial water have differences in their hardness?*"

A brief research on water hardness revealed that there were many water brands containing different levels of hardness and those levels of hardness differed from tap water. In this study, two commercial water brands that are thought to have different levels of hardness were chosen to analyze. Their hardness were analyzed and measured using EDTA titration method. Results of their hardness in the unit of French hardness degree were compared.

Water from tap water were found to have more hardness compared to other commercial water. Remaining two, including Dinç Su and Saka, were softer than tap water compared their hardnesses in the unit of French hardness degree. Between these two commercial waters, the most reliable one was Dinç Su because of its softness. According to the reputation of Saka water of being high quality, I have thought Saka was softer than Dinç Su before the experiment. But according to the results of this study, the hardness was less in Dinç Su following Saka and tap water in their hardness respectively.

Keywords: Water, Hardness, EDTA Titration

Word Count: 234

[1] Understanding Water hardness http://www.ca.uky.edu/wkrec/Hardness.htm

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INTRODUCTION

Quantitative Analysis of Tap Water and Commercial Water Hardness Using Lime Soda Method

Water hardness is a commonly reported as an aspect of quality of water. Hardness of water can be measured by quantity of calcium, magnesium or iron ions. However, calcium and magnesium ions are used most frequently in understanding the hardness of water.

Hardness is usually expressed in terms of the dissolved calcium and magnesium salts calculated as calcium carbonate and non-carbonate equivalent. Therefore, water hardness maybe divided into two classes: carbonated and noncarbonated hardness. These are also known as temporary and permanent hardness respectively. Carbonate or temporary hardness, is caused by bicarbonates of calcium and magnesium; non-carbonate, or permanent hardness, is due to the sulfates and chlorides of calcium and magnesium. Permanent hardness is caused by Mg^{2+} and Ca^{2+} ions and removal of permanent hardness requires the use of chemical agents. Calcium and magnesium ions, that cause hardness, can be found in nature in relatively large numbers. Different water samples may have different levels of hardness according to their ionic content. Classification of water hardness as calcium and calcium carbonate can be seen in Table 1.

Description	Hardness in mg/l as calcium	Hardness in mg/l as calcium carbonate
Soft	0 – 20	0 – 50
Moderately Soft	20 – 40	50 – 100
Slightly Hard	40 – 60	100 – 150
Moderately Hard	60 – 80	150 – 200
Hard	80 – 120	200 – 300
Very Hard	Over 120	Over 300

Table 1: Level of hardness in mg/l as calcium and hardness in mg/l as calcium carbonate at different waters[2].

[2] Hard water conversion http://www.yorkshirewater.com/your-water-services/drinking-water/water-quality/water-hardness.aspx

Hard waters are those containing objectionable amounts of dissolved salts of calcium and magnesium. These are usually present as bicarbonates, chlorides, sulfates, carbonates and nitrates. These salts give insoluble precipitates with soap and calcium sulfate, carbonate and silicate from clogging scales with low thermal conductivity in boilers. Magnesium silicate, as well as calcium carbonate, may reduce heat transfer in process of heat exchangers.

Hardness units are:

- French hardness degree = 10.0 mg $CaCO_3$ / L water
- German hardness degree = 17.8 mg $CaCO_3$ / L water
- English hardness degree =14.3 mg $CaCO_3$ / L water
- 1 ppm $CaCO_3$ = 1 mg $CaCO_3$ / L water

Softening is the term applied to processes which remove or reduce the hardness of water. Softening processes involve two basic processes. These are:

a) Ion Exchanger Processes: Ion exchanger process is a process which contains exchange of ions between two electrolytes. Typical ion exchangers are ion exchange resins, zeolites, montmorillonite, clay, and soil humus.
b) Lime- Soda Processes: The use of slaked lime and of soda ash to remove hardness in water has long been important. Modern application has been divided into two; the cold lime process and hot lime soda process. The calcium ions in hard water are removed as $CaCO_3$ and magnesium ions as Mg $(OH)_2$. Typical equations for these reactions are:[3]

For carbonate hardness:

$$Ca(HCO_3)_2 + Ca(OH)_2 \longrightarrow 2\,CaCO_3 + 2\,H_2O$$
$$Mg(HCO_3)_2 + Ca(OH)_2 \longrightarrow MgCO_3 + CaCO_3 + 2\,H_2O$$
$$MgCO_3 + Ca(OH)_2 \longrightarrow Mg(OH)_2 + CaCO_3$$

- [3] Austin, G.T., Shreve Chemical Process Industries, Fifth edition, Mc Graw Hill International editions, New York, 1984, pp.9.

For non-carbonate hardness:

$MgCl_2 + Ca(OH)_2 \longrightarrow Mg(OH)_2 + CaCl_2$

$CaCl_2 + Na_2CO_3 \longrightarrow CaCO_3 + NaCl$

$CaSO_4 + Na_2CO_3 \longrightarrow CaCO_3 + Na_2SO_4$

$MgSO_4 + Na_2CO_3 \longrightarrow Mg(OH)_2 + CaCO_3 + Na_2SO_4$

METHOD

Ethylene diamine tetra acetic acid (EDTA) titration is one of the best ways of measuring total water hardness. At pH around 10, EDTA easily reacts with both calcium and magnesium in the same mol ratio (1:1). Stability constant of calcium complex is a little bit higher, so calcium reacts first, and magnesium later. To detect the end point, the same indicator which is Eriochrome Black T, were used for both calcium and magnesium. In the case of water that doesn't contain magnesium at all, to be able to detect end point, small amount of magnesium complex were added. Magnesium will be displaced by identical amount of calcium, and it will be titrated later, not changing the final result. However, this is a very rare situation.[4]

Research Question: Do tap water and commercial water have differences with respect to their hardness?

Chemicals and Devices

- 0.02 M Ethylene diamine tetra acetic acid (EDTA) disodium salt solution: 3.720 (±0.001 g) EDTA disodium salt was dissolved in pure water and then diluted to 1000 ml. Solution is adjusted to 0.01 M calcium carbonate solution .
- Buffer solution: 17.300 (±0.001 g) pure NH_4Cl was added to 142.00 (± 0.01 ml) concentrated ammonia (NH_3) solution then diluted to 250.00 (± 0.01 ml).

[4] http://www.titrations.info/EDTA-titration-water-hardness

- Indicator: 1.000 (±0.001 g) Eriochrome Black T and 10.000 (±0.001 g) NaCl were crushed in a mortar and mixed. This solid indicator mixture was stable.
- 5M NaOH (It is used to adjust pH of the sample to 12).
- Calcein indicator: 0.500 (± 0.001 g) calcein was mixed with 100.000 (±0.001) g KNO_3 and then they are grinded. This prepared indicator is stable.
- Water sample: 1000.00 (± 0.01 ml) volume of tap water and commercial water
- Glass equipment:
  Two graduated pipette(1.00 ± 0.01 ml) , pipette (10.00 ± 0.01 ml), Erlenmeyer flask 250.00 ml (± 0.01 ml), Graduated cylinder 250.00 ml (± 0.01 ml)

CONSTANTS AND VARIABLES

Constants

- Temperature
- Concentration of EDTA

Independent Variables

- Hardness of tap and commercial water
- Type of water (commercial, tap)

Dependent Variable

- Volume of EDTA used in titration for determining hardness of water

EXPERIMENTAL PROCEDURE

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1. **Preparation of Buffer Solution**

500 ml beaker was used in order to prepare a buffer solution. It was tared and 17.3 g solid NH_4Cl was weighed. 142 ml ammonia measured with graduated cylinder. Then 17.3 g pure NH_4Cl was added to 142 ml concentrated ammonia. After dissolving NH_4Cl in NH_3, this solution was diluted to 1000 ml with deionized water.

2. **Preparation of EDTA solution**

500 ml beaker was used in order to prepare a buffer solution. 3.72 g EDTA disodium salt was weighed and dissolved in 100 ml deionized water and then diluted to 1000ml.

3. **Preparation of Indicator**

1 g of Eriochrome Black T was measured and crushed with 10 g of NaCl in a mortar.

4. **Preparation of Calcein Indicator**

0.5g Calcein and 100g KNO_3 were measured. Then they were mixed and grinded together. The prepared indicator is stable.

5. **Stabilizing the Constants**

The stabilization of the temperature was not hard. The laboratory where the experiment done must have continuously running air circulation system. This air circulation system stabilizes the temperature at 21-22 ^{0}C.

6. **Titration of Samples**

Titration or titrimetry is a quantitative analysis method. It is done in order to find the amount of analyte. In this study, water samples with the buffer solution and suitable indicator were titrated with EDTA. In this process, water sample, buffer solution and indicator were put in the Erlenmeyer flask and EDTA was put into the burette. EDTA was made to pour into the flask dropwise until the color of the indicator changes. The important point in titration is to have control on the burette tap and detect the exact moment of color change. The consumed EDTA amount was recorded since it is important for the following calculations. A second point to be careful was to perform the titration within 5 minutes after the buffer solution was added into the Erlenmeyer flask. This is because the activity of the buffer solution decreases within long contact times with the sample and indicator. This causes the end point to change. A different end point would mislead us in the hardness detection.

As it can be seen on the following sections, hardness are classified and calculated separately as Total, Total Permanent, Total Calcium and Total Calcium Permanent Hardness. Total Hardness includes both temporary and permanent hardness. For calculating Total Permanent Hardness, water sample was pre-boiled and cooled. This process causes the elimination of bicarbonates of calcium and magnesium in the sample and therefore eliminates temporary hardness. The titration performed afterwards will enable us to find the permanent hardness. Both total permanent hardness and total calcium permanent hardness are aimed to be found. From subtracting the total calcium permanent hardness from total permanent hardness, total magnesium permanent hardness was aimed to be calculated.

7. Determination of Total Hardness

50 ml of water sample was put into a 250 ml Erlenmeyer flask. 10 ml buffer and a few milligrams for Eriochrome Black-T indicator were added and then titrated with 0.02M EDTA solution until its color turns from red to blue. Volume of consumed EDTA was recorded.

8. Determination of Total Permanent Hardness

50 ml of boiled-cooled water sample was put into a 250 ml Erlenmeyer flask. 10 ml buffer and few milligrams of Eriochrome Black – T indicator was added and then titrated with 0.02 M EDTA solution until its color turns from red to blue. Volume of consumed EDTA was recorded.

9. Determination of Total Calcium Hardness

2 ml 5M NaOH was added to 100 ml water sample. After addition of nearly a few milligrams of calcein indicator it is titrated with 0.02 M EDTA until the fluorescence green color of the solution disappears and the violet color appears. Volume of consumed EDTA was recorded.

10. Determination of Total Calcium Permanent Hardness

2 ml 5M NaOH was added to 10 ml boiled - cooled water sample. After addition of nearly a few milligrams of calcein indicator, it is titrated with 0.02 M EDTA until the fluorescence green color of the solution disappears and the violet color appears. Volume of consumed EDTA was recorded.

RESULTS

1. Determination of Total Hardness

2 different samples of water taken from two different brands sold in market and the tap water were analyzed in order to determine their total hardness. Table 2 shows the consumed volumes of EDTA after titration. The calculations in order to reach these results can be seen in the following CALCULATIONS section.

Kind of Water	Volume of EDTA used in titration (± 0.01 ml)
Tap water	6.20
1 st brand water (Saka)	5.30
2 nd brand water (Dinç Su)	4.20

Table 2: Volume of consumed EDTA (± 0.01 ml) after titration with tap water, 1 st brand water (Saka) and 2 nd brand water (Dinç Su).

Volume of consumed EDTA is obtained as it was stated in the METHOD section. From the volume of consumed EDTA the total hardness of waters are calculated in the following section. From the results obtained, it is obvious that tap water has the highest value of total hardness. The results are given below in Table 3:

Kind of Water	Level of total hardness in French Hardness Degree (± 0.01 TH)
Tap water	12.40
1 st brand water (Saka)	10.60
2 nd brand water (Dinç Su)	8.40

Table 3: Levels of total hardness in French hardness degree (± 0.01 TH).

2. Determination of Total Permanent Hardness

2 different samples of water taken from two different brands sold in market and the tap water were analyzed in order to determine their total permanent hardness. Table 4 shows the consumed volumes of EDTA after titration. The calculations in order to reach these results can be seen in the following CALCULATIONS section.

Kind of Water	Volume of EDTA used in titration (± 0.01 ml)
Tap water	6.30
1 st brand water (Saka)	6.00
2 nd brand water (Dinç Su)	3.60

Table 4: Volume of consumed EDTA (± 0.01 ml) after titration with tap water, 1 st brand water (Saka) and 2 nd brand water (Dinç Su).

Table 5 shows the calculated levels of total permanent hardness in 2 brands of water and tap water. From the results obtained it is seen that in French hardness degree tap water had highest level of hardness. 1st commercial water (Saka) and 2nd commercial water (Dinç Su) follows tap water in their level of hardness respectively.

Kind of Water	Level of hardness in French Hardness Degree (± 0.01 TH)
Tap water	12.60
1 st brand water (Saka)	12.00
2 nd brand water (Dinç Su)	7.20

Table 5: Levels of total permanent hardness in French hardness degree (± 0.01 TH).

3. Determination of Total Calcium Hardness

2 different samples of water taken from two different brands sold in market and the tap water were analyzed in order to determine their total calcium hardness. Table 6 shows the consumed volumes of EDTA after titration. The calculations in order to reach these results can be seen in the following CALCULATIONS section.

Kind of Water	Volume of EDTA used in titration (± 0.01 ml)
Tap water	7.90
1 st brand water (Saka)	8.40
2 nd brand water (Dinç Su)	7.00

Table 6: Volume of consumed EDTA (± 0.01 ml) after titration with tap water, 1 st brand water (Saka) and 2 nd brand water (Dinç Su).

Table 7 shows the calculated levels of total calcium hardness in 2 brands of water and tap water. Unlike the level of total hardness and total permanent hardness, 1st commercial water had the highest level total calcium hardness. Tap water and 2nd commercial water follows it respectively.

Kind of Water	Level of hardness in French Hardness Degree (± 0.01 TH)
Tap water	15.80
1 st brand water (Saka)	16.80
2 nd brand water (Dinç Su)	14.00

Table 7 : Levels of total calcium hardness in French hardness degree (± 0.01 TH).

4. Determination of Total Calcium Permanent Hardness

2 different samples of water taken from two different brands sold in market and the tap water were analyzed in order to determine their total permanent calcium hardness. Table 8 shows the consumed volumes of EDTA after titration. The calculations in order to reach these results can be seen in the following CALCULATIONS section.

Kind of Water	Volume of EDTA used in titration (± 0.01 ml)
Tap water	9.00
1 st brand water (Saka)	9.00
2 nd brand water (Dinç Su)	5.00

Table 8: Volume of EDTA after performing titration (± 0.01 ml) and 2 brand name of water and tap water.

Volume of consumed EDTA is obtained as it was stated in the METHOD section. From the volume of consumed EDTA the total calcium hardness of waters are calculated in the following section. From the results obtained, it is obvious that tap water has equal value of total calcium permanent hardness with 1st commercial water . The results are given below in Table 9:

Kind of Water	Level of total hardness in French Hardness Degree (± 0.01 TH)
Tap water	18.00
1 st brand water (Saka)	18.00
2 nd brand water (Dinç Su)	10.00

Table 9: Level of total calcium permanent hardness in French hardness degree (± 0.01 TH).

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D1129069

CALCULATIONS

After titrations are performed, water hardness can be calculated as shown below:

Formula weight of EDTA disodium salt is 372 g.

Formula weight of $CaCO_3$ is 100g.

1000 ml of 0.02 M is equivalenced with 1 g $CaCO_3$ so;

1 ml 0.02 M EDTA is equivalanced with 1 mg $CaCO_3$.

According to all of the things stated above, equation to be used for water hardness calculation is;

Hardness of water sample in ppm for $CaCO_3$=

$$\frac{\text{Volume of EDTA solution used}}{\text{Volume of Water Sample In L}} \cdot \frac{\text{1 mg equivalent CaCO3}}{\text{1 ml of 0.02 M EDTA solution}}$$

1. Determination of Total Hardness

a. Tap water

The equation for total hardness of tap water is;

$$\frac{\text{6.2 ml of 0.02 M EDTA solution}}{\text{0.05 L water sample}} \cdot \frac{\text{1 mg equivalent CaCO3}}{\text{1 ml of 0.02 M EDTA solution}}$$

= 124 mg $CaCO_3$ /L water sample

= 124 ppm for $CaCO_3$

French Hardness Degree = 10.0 mg $CaCO_3$ /L water so;

Total hardness of tap water sample in ppm for $CaCO_3$= 124 ppm = 12.4 TH

b. 1 st Commercial water (Saka)

The equation for total hardness of 1st commercial water (Saka) is;

$$\frac{5.3 \text{ ml of } 0.02 \text{ M EDTA solution}}{0.05 \text{ L water sample}} \cdot \frac{1 \text{ mg equivalent CaCO3}}{1 \text{ ml of } 0.02 \text{ M EDTA solution}}$$

= 106 mg $CaCO_3$ /L water sample

= 106 ppm for $CaCO_3$

French Hardness Degree = 10.0 mg $CaCO_3$ /L water so;

Total hardness of 1st commercial water (Saka) sample in ppm for $CaCO_3$ = 106 ppm = 10.6 TH

c. 2nd Commercial Water (Dinç Su)

The equation for total hardness of 2nd commercial water (Dinç Su) is;

$$\frac{4.2 \text{ ml of } 0.02 \text{ M EDTA solution}}{0.05 \text{ L water sample}} \cdot \frac{1 \text{ mg equivalent CaCO3}}{1 \text{ ml of } 0.02 \text{ M EDTA solution}}$$

= 84 mg $CaCO_3$ /L water sample

= 84 ppm for $CaCO_3$

French Hardness Degree = 10.0 mg $CaCO_3$ /L water so;

Total hardness of 2nd commercial water (Dinç Su) sample in ppm for $CaCO_3$ = 84 ppm = 8.4 TH

2. Determination of Total Permanent Hardness

a. Tap water

The equation for total permanent hardness of tap water is;

$$\frac{6.3 \text{ ml of } 0.02 \text{ M EDTA solution}}{0.05 \text{ L water sample}} \cdot \frac{1 \text{ mg equivalent CaCO3}}{1 \text{ ml of } 0.02 \text{ M EDTA solution}}$$

= 126 mg $CaCO_3$ /L water sample

= 126 ppm for $CaCO_3$

French Hardness Degree = 10.0 mg $CaCO_3$ /L water so;

Total permanent hardness of tap water sample in ppm for $CaCO_3$= 126 ppm = 12.6 TH

b. 1st Commercial water (Saka)

The equation for total permanent hardness of 1st commercial water (Saka) is;

$$\frac{6.0 \text{ ml of } 0.02 \text{ M EDTA solution}}{0.05 \text{ L water sample}} \cdot \frac{1 \text{ mg equivalent CaCO3}}{1 \text{ ml of } 0.02 \text{ M EDTA solution}}$$

=120 mg $CaCO_3$ /L water sample

=120 ppm for $CaCO_3$

French Hardness Degree = 10.0 mg $CaCO_3$ /L water so;

Total permanent hardness of 1st commercial water (Saka) sample in ppm for $CaCO_3$ = 120 ppm = 12.0 TH

c. 2nd Commercial Water (Dinç Su)

The equation for total permanent hardness of 2nd commercial water (Dinç Su) is;

$$\frac{3.6 \text{ ml of } 0.02 \text{ M EDTA solution}}{0.05 \text{ L water sample}} \cdot \frac{1 \text{ mg equivalent CaCO3}}{1 \text{ ml of } 0.02 \text{ M EDTA solution}}$$

= 72 mg $CaCO_3$ /L water sample

= 72 ppm for $CaCO_3$

French Hardness Degree = 10.0 mg $CaCO_3$ /L water so;

Total permanent hardness of 2nd commercial water (Dinç Su) sample in ppm for $CaCO_3$ = 72 ppm = 7.2 TH

3. Determination of Total Calcium Hardness

a. Tap water

The equation for total calcium hardness of tap water is;

$$\frac{7.9 \text{ ml of } 0.02 \text{ M EDTA solution}}{0.05 \text{ L water sample}} \cdot \frac{1 \text{ mg equivalent CaCO3}}{1 \text{ ml of } 0.02 \text{ M EDTA solution}}$$

= 158 mg $CaCO_3$ /L water sample

= 158 ppm for $CaCO_3$

French Hardness Degree = 10.0 mg $CaCO_3$ /L water so;

Total calcium hardness of tap water sample in ppm for $CaCO_3$ = 158 ppm = 15.8 TH

b. 1st Commercial water (Saka)

The equation for total calcium hardness of 1st commercial water (Saka) is;

$$\frac{8.4 \text{ ml of } 0.02 \text{ M EDTA solution}}{0.05 \text{ L water sample}} \cdot \frac{1 \text{ mg equivalent CaCO3}}{1 \text{ ml of } 0.02 \text{ M EDTA solution}}$$

= 168 mg $CaCO_3$/L water sample

= 168 ppm for $CaCO_3$

French Hardness Degree = 10.0 mg $CaCO_3$/L water so;

Total calcium hardness of of 1st commercial water (Saka) in ppm for $CaCO_3$ = 168 ppm = 16.8 TH

c. 2nd Commercial Water (Dinç Su)

The equation for total calcium hardness of 2nd commercial water (Dinç Su) is;

$$\frac{7.0 \text{ ml of } 0.02 \text{ M EDTA solution}}{0.05 \text{ L water sample}} \cdot \frac{1 \text{ mg equivalent CaCO3}}{1 \text{ ml of } 0.02 \text{ M EDTA solution}}$$

= 140 mg $CaCO_3$/L water sample

= 140 ppm for $CaCO_3$

French Hardness Degree = 10.0 mg $CaCO_3$/L water so;

Total calcium hardness of of 2nd commercial water (Dinç Su) sample in ppm for $CaCO_3$ = 140 ppm = 14.0 TH

4. Determination of Total Calcium Permanent Hardness

a. Tap water

The equation for total calcium permanent hardness of tap water is;

$$\frac{9.0 \text{ ml of } 0.02 \text{ M EDTA solution}}{0.05 \text{ L water sample}} \cdot \frac{1 \text{ mg equivalent CaCO3}}{1 \text{ ml of } 0.02 \text{ M EDTA solution}}$$

= 180 mg $CaCO_3$ /L water sample

= 180 ppm for $CaCO_3$

French Hardness Degree = 10.0 mg $CaCO_3$ /L water so;

Total calcium permenant hardness of tap water sample in ppm for $CaCO_3$ = 180 ppm = 18.0 TH

b. 1 st Commercial water (Saka)

The equation for total permanent calcium hardness of 1st commercial water (Saka) is;

$$\frac{9.0 \text{ ml of } 0.02 \text{ M EDTA solution}}{0.05 \text{ L water sample}} \cdot \frac{1 \text{ mg equivalent CaCO3}}{1 \text{ ml of } 0.02 \text{ M EDTA solution}}$$

= 180 mg $CaCO_3$ /L water sample

= 180 ppm for $CaCO_3$

French Hardness Degree = 10.0 mg $CaCO_3$ /L water so;

Total calcium permanent hardness of 1st commercial water (Saka) sample in ppm for $CaCO_3$ = 180 ppm = 18.0 TH

***c.* 2nd Commercial Water (Dinç Su)**

The equation for total calcium hardness of 2nd commercial water (Dinç Su) is;

$$\frac{5.0 \text{ ml of } 0.02 \text{ M EDTA solution}}{0.05 \text{ L water sample}} \cdot \frac{1 \text{ mg equivalent CaCO3}}{1 \text{ ml of } 0.02 \text{ M EDTA solution}}$$

= 100 mg $CaCO_3$ /L water sample

= 100 ppm for $CaCO_3$

French Hardness Degree = 10.0 mg $CaCO_3$ /L water so;

Total calcium permanent hardness of 2nd commercial water (Dinç Su) sample in ppm for $CaCO_3$ = 100 ppm = 10.0 TH

5. **Percent Error Calculation**

According to literature, 1st commercial water (Saka) has 8,5 TH total permanent hardness.

2nd commercial water (Dinç Su) has 3,2 TH total permanent hardness.

and tap water in Ankara has 10,2 TH total permanent hardness.

The equation for finding percent error is;

$$\frac{|\text{Literature value} - \text{Experimental Value}|}{\text{Literature value}} \times 100$$

- So our percent error for 1st commercial water (Saka) is;

$$\frac{|8.5\ \text{TH} - 12.0\ \text{TH}|}{8.5\ \text{TH}} \times 100\%$$

= 41. 2%

- Our percent error for 2nd commercial water (Dinç Su) is;

$$\frac{|7.2\ \text{TH} - 5.2\ \text{TH}|}{5.2\ \text{TH}} \times 100\%$$

=38.5%

- Our percent error for tap water is;

$$\frac{|\,12.4\ \mathrm{TH} - 10.2\ \mathrm{TH}\,|}{10.2\ \mathrm{TH}} \times 100\%$$

= 21.6 %

CONCLUSION and DISCUSSION

Hard water is water that has high mineral content. It has high concentrations of Ca^{2+} and Mg^{2+} ions and can pose serious problems in industrial settings, where water hardness is monitored to avoid costly breakdowns in boilers, cooling towers, and other equipment that handles water.[5]

Hard water has high concentration of both dissolved calcium and magnesium. All kind of natural waters contain anions and cations. As the water flows, it dissolves many ions. Although water hardness is defined as the quantity of cations with a +2 or +3 charge, calcium ion and magnesium ion are most common of such ions in natural water.[6]

Although it is a common mistake that hard water is harmful for human health, hardness does not cause a health risk. However, calcium and magnesium in your drinking water help you in order to get average daily requirements in your diet. But hard water can be a nuisance due to the mineral buildup on plumbing fixtures and poor soap and detergent performance. Its alkali taste caused by hardness may make your coffee taste bitter, can lead to lower water pressure in pipes; build-up of deposits on dishes. Using soft water in laundry helps whites bright slow down the fading of colored clothes. However, hard water also causes difficulty in getting soap and detergent to foam; and lowered efficiency of electric water heaters[7]

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[5] Hard water: http://en.wikipedia.org/wiki/Hard_water
[6] Water hardness: www.gannon.edu/resource/dept/.../pH%20water%20hardness.pdf)
[7] Uses of Soft Water for Cleaning | eHow.com http://www.ehow.com/way_5545277_uses-soft-water-cleaning.html#ixzz1Sv0vKj2P

In this study, to answer the question whether the hardness of tap water differs from commercially available waters is aimed. In order to answer, Saka and Dinç Su, two different water brands that have a reputation of having different qualities are chosen. Saka is believed to be of higher quality than Dinç Su. Titration of all 3 samples of water, tap water, Saka and Dinç Su respectively were performed with EDTA. From the point that color of the indicator changes, the consumed EDTA was recorded. Within necessary calculations, the $CaCO_3$ concentration is found in ppm. Then the results in ppm are converted into TH. According to these series of calculations, the results are like shown below:

Type of Water	Total Permanent Hardness(TH)
Tap Water	12.6
1 st commercial water (Saka)	12.0
2nd commercial water (Dinç Su)	7.2

Table 10: Data for total permanent hardness (TH) for different types of water.

According to literature, 1st commercial water (Saka) has 8.5 TH total permanent hardness, 2nd commercial water (Dinç Su) has 3.2 TH total permanent hardness and tap water in Ankara has 10.2 TH total permanent hardness. Comparing these values with the experimental values, the percent error of the experimentation process of tap water is 21.6%, the percent error of the experimentation process of Saka is 41.2% and the percent error of the experimentation process of Dinç Su is 38.5%. These values of percent error are all acceptable as they are below fifty percent. This tells us that our study can be stated as fairly accurate. Also as the three percentages are close to each other, precision of the study can be classified as high. This states that no systematic error is done in any of the three parts of experimentation and the percent error is caused by the insufficient calibration of the glassware or any human insufficiencies.

In order to decrease the amount of error in this study, imperfections in the measuring instruments that cause instrumental error should be fixed. More precise measuring devices such as graduated cylinders instead of beakers should be used. Also a more experienced researcher who has done more titrations before would be able to detect the point of color change more accurately, leading to a low level of percent error.

This study considers the water taken from the tab of the laboratory (in Beytepe Ankara) to represent the tab water of Ankara and this may cause some limitations and give rise to some error. To obtain an average value from different samples would decrease the amount of error. For further studies exploring the water hardness, hardness of tab water taken from different tabs through Ankara can be measured and an average value of water hardness in Ankara can be found. In addition to all of the things stated above, only two of the commercial brands that are chosen randomly were studied and exploring the hardness of other brands of commercial water might be useful in getting knowledge about deciding which one to drink.

According Hilton Head PSD Water Hardness Guide it is said that:

17 to 60 parts per million (ppm) $CaCO_3$ =============➔ Slightly Hard

60 to 120 ppm $CaCO_3$ ========================➔ Moderately Hard

120 to 180 ppm $CaCO_3$ =======================➔ Hard

More than 180 ppm $CaCO_3$ ====================➔ Very Hard

According to our experimental results; as the total permanent hardness of tap water is over 12.0 TH, tap water must be considered as hard water. As the total permanent hardness of 1st commercial water is 12.0 TH it must be considered as moderately hard water. As the total permanent hardness of 2nd commercial water is between 6.0 TH and 12.0 TH it must be considered as moderately hard water. Therefore all the waters examined are found to have hardness above average. From the results obtained it is evaluated that tap water has highest degree of hardness. Level of hardness following 1 st commercial water and 2nd commercial water. Also it is evaluated that it’s better to drink the water that has level of hardness between tap water and 1st commercial water.

Berk NAMAL
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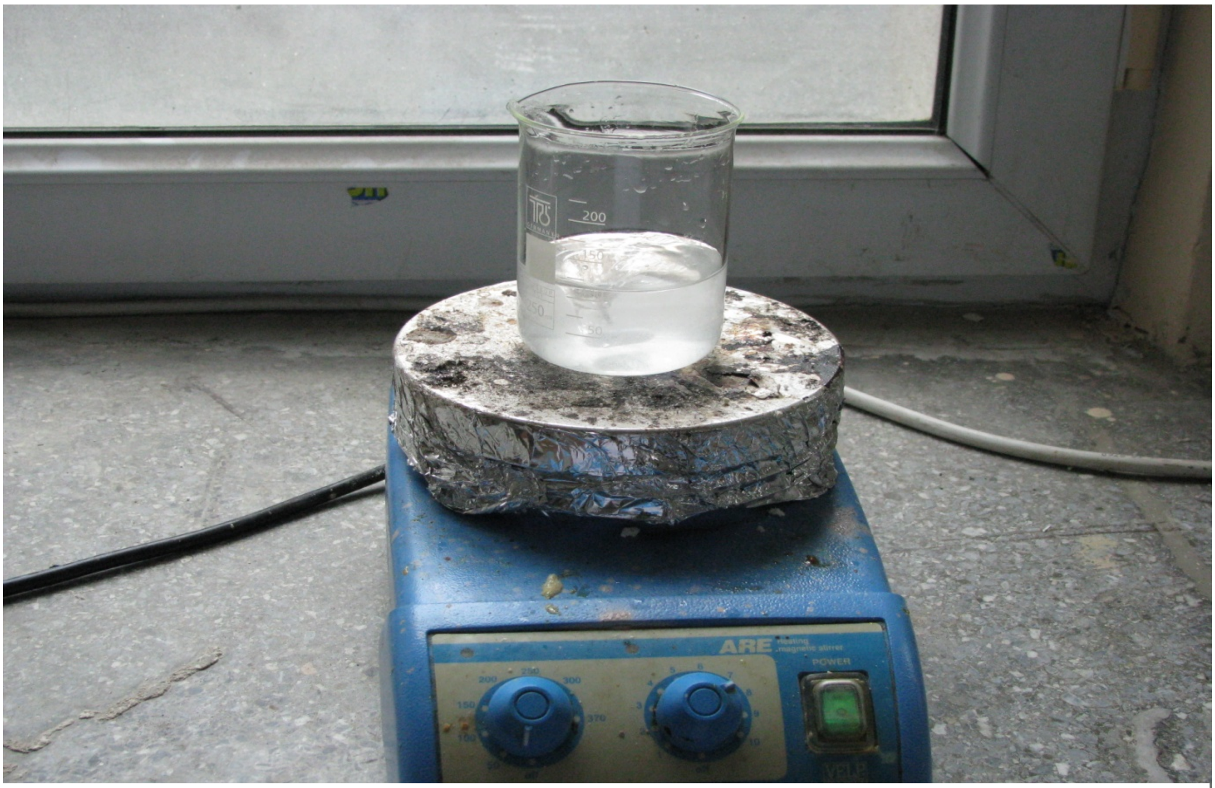
Appendix 1: (Photographs)

List of Pictures

Picture 1: Equipment of the experiment


29

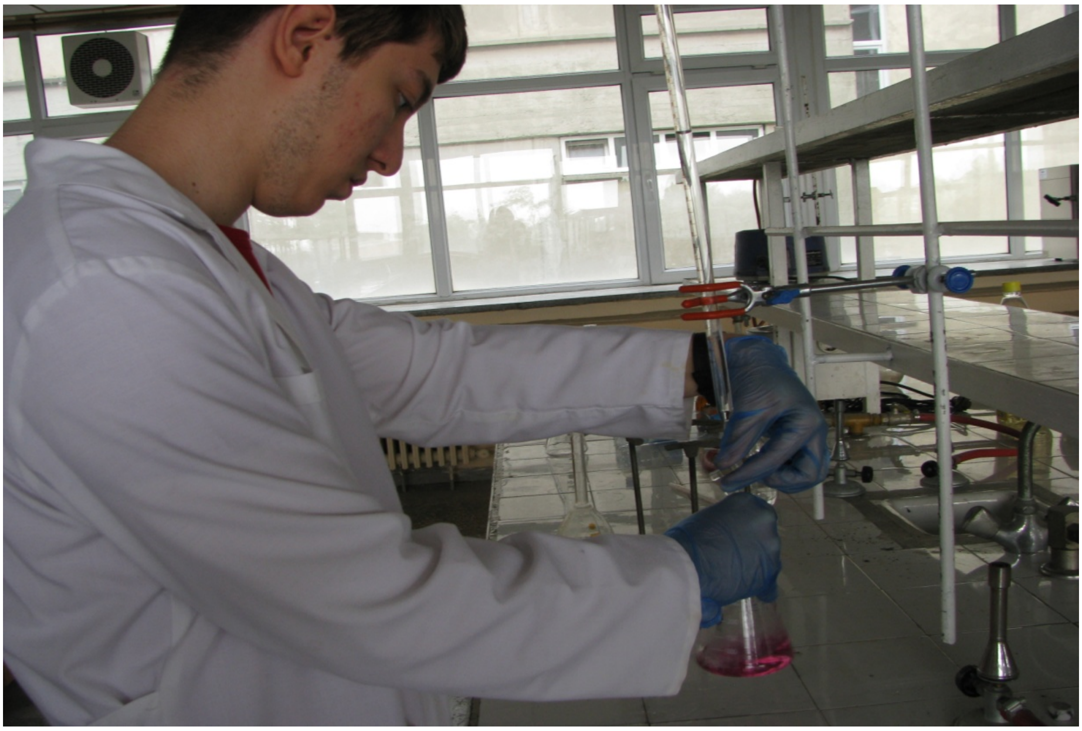
Picture 2: Preparation of indicator



Picture 3: Magnetic Stirrer for a better dissolving

Picture 4: Preparation of Solutions

Picture 5: Preparation of solutions



Picture 6: Titration Process

Picture 7: Water, solutions and equipments used in the experiment