Determination of some Inorganic Constituents of Ground Water in Sennar, Sennar State, Sudan

By
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A Dissertation
Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Science in Chemistry
Department of Applied Chemistry and Chemical Technology
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Co. Supervisor : Dr. Mohamed Osman Babiker Ahmed

April, 2013
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Supervision Committee:

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Date of Examination: 10/4/2013
Dedication

To my mother

To my father

To my friends
Acknowledgement

I would like to express special and deep thanks to my supervisor Dr. FathElrahman Abbas Elshikh for his help and advice, encouragement, support and guidance and his endless patience for every thing, in this study.

Special thanks to the Staff of Chemistry Department for their efforts and advice, and to lab Technicians.
Determination of some Inorganic Constituents of Ground Water in Sennar, Sennar State, Sudan

Mohammed Eissa Omer Ahmed
M.Sc. in chemistry (April, 2013)
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ABSTRACT

Well water is the main source of drinking water in Sennar city. The aim of this study was to determine quantitatively the inorganic constituents of drinking water in Sennar city and to compare their concentration with WHO standards. Six samples of water were collected from six ground wells in different locations at Sennar city – Sennar state – Sudan. The analysis was done for the following parameters. PH, EC, TDs, anions (Cl⁻, SO₄²⁻, CO₃²⁻, HCO₃⁻), hardness as CaCO₃ and some of cations as (Ca²⁺, Na⁺, K⁺). The results showed that all samples (Kaboosh, Rahhal, Elabasia, Elmazad 39, Elthawra) and West Elgalaa are alkaline according to the values of PH. TDs values for all the samples are within the permissible level of WHO. The chloride concentrations of the samples are in agreement with the WHO standards. The sulphate ions concentrations are in the permissible level of WHO. The cations (Na⁺, K⁺, and Ca²⁺) were found to be within the maximum level of WHO standards. Sample A is classified as moderately hard, samples (Rahhal, Elabasia, Elmazad 39, Elthawra) are hard, and sample West Elgalaa is very hard. From the results it can be seen that all the samples are within the permissible level of WHO standards. Thus, Sennar water is suitable for all human use.
تحديد بعض المكونات الغير عضوية لمياه الأبار في سنار ، ولاية سنار ، السودان

محمد عيسى عمر أحمد

ماجستير العلوم في الكيمياء (أبريل ، 2013م)
قسم الكيمياء التطبيقية وتكنولوجيا الكيمياء
كلية الهندسة والتكنولوجيا
جامعة الجزيرة

الخلاصة

مياه الأبار هي المصدر الرئيسي لمياه الشرب في مدينة سنار الهدف من هذه الدراسة
تحديد بعض المكونات الكيميائية اللاعضوية لماء الشرب في مدينة سنار ومقارنة تراكيزها مع
القيم الموصى بها من قبل منظمة الصحة العالمية جمعت ستة عينات من مياه أبار جوفية من
مناطق مختلفة في مدينة سنار. تم حللة العوامل الفيزيائية والكيميائية الآتية: —
الأساليدروجيني،الموصلية الكهربائية،الأملاح الدائمة،الأيونات السالبة (SO₄²⁻،CO₃⁻²،HCO₃⁻،Cl⁻)،
أوضحت النتائج أن العينات قاعدية حسب قيم الأس الهيدروجيني، الأملاح الكلية ذاتية في العينات تتوافق بما أوصت به
منظمة الصحة العالمية. أوضحت النتائج أيضاً أن تراكيز الأيونات الكلورية والكبريتات تتوافق
بما أوصت به منظمة الصحة العالمية، أما الأيونات الموجبة (صوديوم غوتانسيوم، كالسيوم)
فهي تتوافق بما أوصت به منظمة الصحة العالمية. العينة كبوس صنفتها متوسطة العمر
والعينات (رحال، العباسية، المزاد 39، النورة) عسرة وعينة القلعة غرب عسرة
أوضحت النتائج أن جميع العينات مطابقة لمواصفات منظمة الصحة العالمية لذلك فهي
صالحة للاستخدام البشري.
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Chapter one
Introduction

Water is one of the most important chemicals known to man. Without it neither animals nor plants life will exist.

Water is essential for the processes of digestion, circulation, elimination and the regulation of body temperature.

Water is used as a solvent for many substances, (Georgal and Schultz 1973).

Almost three fourth of the earth’s surface is covered by water most of this water is not suitable for human use.

The demand for fresh water has increased with rapid growth of population, agriculture, and industry, (Abdelgafar, 1999).

1.1 Water Sources:

The sources of water supply are divided into two major classes, surface and ground water.

1.1.1 Surface water:

Surface water includes rivers, lakes, seas, ponds and reservoirs (WHO, 1993). Surface water is easily contaminated and the total bacterial and fungal contents are high, thus it requires proper treatment before its consumption. Simple treatments such as filtration and chlorination are important to make it suitable for human consumption.

1.1.2 Ground water:

Ground water is supplied from rivers, reservoirs and marshes. Ground water comes into contact with various minerals which are soluble in water. The dissolved minerals beyond certain limits may make it unsuitable for irrigation, drinking or industrial purposes. In many
countries ground water is the main source of water for all purpose. This is because rural communities are found close to the ground water. Ground water can be classified into three classes according to the layer in which it is found (IDC, 1981).

(i) **Ground water:**

It is the water that collects above the first stable impervious layer of rock. It is supplied mainly by rain water or percolation of rivers or lakes.

(ii) **Artesian waters:**

Artesian water is stored in a water containing layer sandwiched between two impervious layers.

(iii) **Perched water:**

Perched water exists above a sectional impervious layers. It is widely distributed and is seasonal. Deep ground water may contain various kinds of salts and can be very hard.

**1.2 General Properties of ground water:**

Water properties are classified into physical and chemical properties.

**1.2.1 physical properties of ground water:**

The Physical properties of water are:

1.2.1.1 **Temperature:**

In general the rate of chemical reaction decrease, with decreasing temperature. The relative concentration of reactants and products in chemical equilibria can also change with temperature. Turbidity and colour are inversely related to temperature, as the efficiency of coagulation is strongly temperature dependant.

1.2.1.2 **Density:**

The density of pure water is 1g/ml at 4°C. Density decreases with the increase of temperature. Water exists in three states solid, liquid and gas.
1.2.1.3 Colour:

Colour in water may result from the presence of natural metallic ions (iron and manganese), human peat materials, weeds and industrial wastes. Colour is removed to make water suitable for general and industrial application.

1.2.1.4 Odour:

Odour depend on contact of a stimulating substance with the appropriate human receptor cells. In it's pure form, water is odour free. Odour is recognized as quality factor affecting acceptability of drinking water.

1.2.1.5 Turbidity:

Water is turbid when it contains visible materials in suspension. While turbidity may result from living and dead algae or other organisms, it is generally caused by silt or clay.

The amount and character of turbidity will depend upon the type of soil over which the water has run and the velocity of water.

1.2.1.6 Electrical conductivity (EC):

Electrical conductivity is the measure of ability of water to conduct an electric current that passes through it. EC is proportional to the amount of TDS in water and it is an excellent indicator of TDS in water. Electrical conductivity is expressed in micro mhos per centimeter (µMhos/cm) or expressed in micro Siemens per centimeter (µS/cm) (Twort et al, 1985).

1.2.1.7 Total dissolved Solids (TDS):

Total dissolved solids (TDS) comprise inorganic salts (principally calcium, magnesium, potassium, sodium for cations and carbonate, bicarbonate, chloride, sulphate and nitrate for onions) and small amounts
of organic matter that dissolves in water. Concentration of TDS in water vary considerably in different geological regions owing to difference in solubility of minerals. TDS can be expressed in ppm and it is directly related to the conductivity (WHO, 1993).

The water with the total dissolved solids level of less than 600 mg/L is generally considered to be good. Drinking water becomes increasingly unacceptable when TDS levels are greater than 1200 mg/L. Table (1.1) shows Health criteria for TDS(WHO,1989).

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<th>Range mg/L TDS</th>
<th>TDS level</th>
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<td>Less than 300</td>
<td>Excellent</td>
</tr>
<tr>
<td>300 – 600</td>
<td>Good</td>
</tr>
<tr>
<td>600 – 900</td>
<td>Accepted</td>
</tr>
<tr>
<td>900 – 1200</td>
<td>Bad</td>
</tr>
<tr>
<td>Over 1200</td>
<td>Un acceptable</td>
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1.2.2 Chemical Properties of water:

Chemical properties enable us to classify the water, find the degree of pollution and cause of sharp increase of polluting substances .The chemical properties include:

1.2.2.1 pH:

The pH is the negative common logarithm of hydrogen ion activity in moles per liter (WHO, 1984- b).

The pH of most natural waters falls within the range 4 to 9. Water with a pH = 7.00 is neutral, at pH value greater than 7.00 indicates that
water is alkaline. If the pH value is very low (less than 4) water will have acidic taste. High pH can give taste problems and soapy feel. Temperature plays a role in the value of pH at which neutrality occurs (Flatcher, 1989).

**Determination of pH:**

pH is determined by pH meter.

**1.2.2.2. Alkalinity:**

Alkalinity is a measure of ability of water to neutralize acids and it is represented by carbonate (CO$_3^{2-}$), bicarbonate (HCO$_3^-$) or hydroxide (OH) compound. Alkalinity (calculated as CaCO$_3$) limit depends upon the method used for softening water.

**1.2.2.3 Chloride:**

Chloride is one of the major anions in water. Chlorides are present as sodium chloride (NaCl) and to lesser extent as calcium and magnesium chloride (Abdelgafar, 1999).

The main problem caused by excessive chloride in water concerns the acceptability of the supply. Concentration above 50 mg/L can impart a distinctly salty taste to water (Towrt, et al, 1985).

For people suffering from heart and kidney diseases, high chloride water usage has to be restricted (WHO, 1993). Excessive chloride concentration increases rates of corrosion of metals in the distribution system.

**Determination of Chloride:**

Chloride is determined by the most common precipitation titrimetric method (Mohr Method)

\[\text{Ag}^+ + \text{Cl}^- \rightarrow \text{AgCl} \downarrow \text{ (White ppt)}\]

\[2\text{Ag}^+ + \text{CrO}_4^{2-} \rightarrow \text{Ag}_2\text{CrO}_4 \downarrow \text{ (red ppt)}\]
Another method is photometric method in which the chloride of the water is determined photo electrically using the plain test Photometer. The samples should be filtered to remove suspended solids before analysis. The chloride of water is expressed using the platinum /Cobalt chloride scale (PT/CO scale) (Sarah, 2012).

* Ion chromatography may also be used for chloride determination.

* The argentometric method is suitable for relatively clear water. The end point of mercuric nitrate method is easier to detect.

* The potentiometric method is suitable for coloured or turbid samples in which colour indicated end point may be difficult to observe.

1.2.2.4 Sulphate:

The concentration of sulphate in natural water can be found in various ranges from a few mg/L to several thousand mg/L. The highest level usually occurs in the ground water. The sources of sulphate are the solution of minerals containing sulphates and oxides of sulphur, sulphides and thiosulphates. The presence of sulphate in drinking water can cause noticeable taste. The taste varies with the associated cation. Test threshold has been found to range from 250 mg/L for Sodium sulphate to 1000mg/L for calcium sulphate (WHO, 1993). Sulphate in domestic water contributes to the majority of non carbonate or permanent hardness.

High levels of sulphate can impart taste and when combined with magnesium or sodium can have laxative effect (WHO, 1993).

**Determination of Sulphate:**

\[ \text{SO}_4^{2-} \text{can be determined as BaSO}_4 \text{ by Barium Chloride} \]

\[ \text{SO}_4^{2-} + \text{BaCl}_2 \rightarrow \text{BaSO}_4 \downarrow + 2\text{Cl}^- \]

White ppt
1.2.2.5 Carbonate and bicarbonate:

Carbonate and bicarbonate in water are two of the three components of the carbonates equilibrium. The variation of pH of water affects the concentration of carbonate ions, if the pH is less than 4.5, water is free from carbonic acid when pH is above 8.3 then carbonic acid content is disregarded. The concentration of carbonic acid and bicarbonates are usually high in ground water. High concentration of carbonic acid in water makes the water corrosive to metals and concrete (Abdella, 2001).

Determination of carbonate and bicarbonate:

Determine of carbonate and bicarbonate by titrimetric method

\[ \text{HCO}_3^- + \text{HCl} \rightarrow \text{H}_2\text{O} + \text{CO}_2 + \text{Cl}^- \]
\[ \text{CO}_3^{2-} + 2 \text{HCl} \rightarrow \text{CO}_2 + 2\text{H}_2\text{O} + 2\text{Cl}^- \]

1.2.2.6 Hardness:

Hardness in water is caused by metallic ions which are capable of precipitating soap. The hardness of water is due to the presence of bicarbonate, sulphate and chloride of calcium and magnesium. There are two types of hardness

* Temporary hardness: (carbonate hardness) which is due the presence of bicarbonate this type can be removed by boiling the water and precipitation of CaCO\(_3\) and MgCO\(_3\).

\[ \text{Ca} (\text{HCO}_3^-)_2 \xrightarrow{\Delta} \text{CaCO}_3 + \text{H}_2\text{O} + \text{CO}_2 \]
\[ \text{Mg} (\text{HCO}_3^-)_2 \xrightarrow{\Delta} \text{MgCO}_3 + \text{H}_2\text{O} + \text{CO}_2 \]

* Permanent hardness: Which due to the presence of chloride and sulphate. This hardness can be eliminated by chemical reaction (precipitation). Water hardness is expressed as ppm CaCO\(_3\).

\[ \text{Ca}^{2+} (\text{aq}) + \text{CO}_3^{2-} (\text{aq}) \rightarrow \text{CaCO}_3(\text{s}) \]
\[ \text{Mg}^{2+} (\text{aq}) + \text{CO}_3^{2-} (\text{aq}) \rightarrow \text{MgCO}_3(\text{s}) \]
Removal of hardness:

-by the use of Soda:

Soda removes both temporary and permanent hardness. The addition of soda results in precipitation of calcium and magnesium ions as calcium and magnesium carbonates.

-Ion exchange process:

Ion exchange process is a chemical method by which softening of permanent hardness in water can be done on a large scale or for household process.

Determination of hardness:

*EDTA titermetric method was used as an standard method.

\[
\text{EDTA + Ca}^{+2}+\text{Mg}^{+2} \rightarrow \text{EDTA Ca Mg}
\]

Eriochrome black T indicator was used. The colour changes from red to blue.

*Plaintest photometer is another method used to test for water hardness by using calcium hardness test which is based on the calcicol indicator reagent method. Calcium ion react specifically with calcicol indicator in alkaline solution to give orange coloration. The reagent itself gives a violet colour in solution. The reagents are provided in the form of two tablets. The test is carried out simply by adding one of each tablet to a sample of water. The colour produced is indicative of the calcium hardness and magnesium using a plain test photometer. (Sarah, 2012).

Table (1.2) shows the classification of water on the basis of hardness.
Table (1.2) Classification of water on basis of hardness.

<table>
<thead>
<tr>
<th>Range CaCo3 (mg/L)</th>
<th>Hardness Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 – 50</td>
<td>Soft</td>
</tr>
<tr>
<td>50 – 100</td>
<td>Moderately soft</td>
</tr>
<tr>
<td>100 – 150</td>
<td>Slightly hard</td>
</tr>
<tr>
<td>150 – 200</td>
<td>Moderately hard</td>
</tr>
<tr>
<td>200 – 300</td>
<td>Hard</td>
</tr>
<tr>
<td>Over 300</td>
<td>Very hard</td>
</tr>
</tbody>
</table>

Source: (Twort et al,1985).

1.2.2.7 Sodium:

Sodium is a major constituent of natural water. It has been estimated that food accounts for approximately 90% of the daily intake of Na\(^+\) whereas drinking water contributes the remaining 10% (Elnour, 2004). Sodium is an acutely toxic metal, and the body has a very effective method of controlling sodium levels.

**Determination of Sodium and Potassium:**

Sodium and Potassium are determined by Flame photometer.

Principle: Measure emission intensity of atom after electronic excitation in flame.

\[
\text{NaCl}_\text{(L)} \xrightarrow{\text{flame}} \text{NaCl}_\text{(s)} \xrightarrow{\text{flame}} \text{NaCl}_\text{(g)}
\]

The fact Na and K emit coloured flame from organic sources is well known and called flame test qualitative analysis. This process can be used for quantitative analysis. The emission (EI) is directly proportional to the concentration (C).

\[
\text{EI} \propto C
\]

\[
\text{EI} = KC
\]
1.2.2.8 Potassium:

It is an essential element in both plant and human nutrition, and occurs in ground waters as a result of minerals dissolution, from decomposing plant material and from agricultural run off. The common aqueous species is K⁺. Unlike sodium it does not remain in solution, but is assimilated by plants and incorporated into a number of clay mineral structures (APHA, et al., 1971).

1.2.2.9 Calcium:

The average abundance of Calcium in the earth's crust is 4.9%, in soil it is 0.07 to 1.7 %, in streams it is about 15 mg/L; and in ground water it is 1 to 500 mg/L. The most common forms of calcium are calcium carbonate (calcite) and calcium_ magnesium_ carbonate (dolomite). Calcium compounds are widely used in pharmaceuticals, photography, lime, de-icing salt, pigments, fertilizer and plasters (APHA, 1998). Calcium carbonate solubility is controlled by pH and dissolved CO₂. The CO₂, HCO⁻₃ and CO₃⁻² equilibrium is the major buffering mechanism in fresh water. Hardness based on concentration of calcium and magnesium salts and often is used as a measure of potable water quality (APHA, 1998).

Calcium is necessary in plant and animal nutrition and is an essential component of bones, shells and plant structures. The presence of calcium in water supplies results from passage over deposits of limestone, dolomite, gypsum and pest ferrous shale. Small concentration of Calcium carbonate combat corrosion of metal pipes by laying down a protective coating. Precipitation of calcium in domestic and industrial water is often controlled by water softening (e.g., ion exchange) (APHA, et al. 1998). Calcium contributes to the total hardness of water. Chemical softening treatment reverse osmosis, electro dialysis or ion exchange are used to reduce calcium and associated hardness. Calcium concentration in
neutral waters are typically < 15 mg/L. For water associated with carbonate rich rocks concentration may reach 10 – 30 mg/l (Chapman1996).

**Determination of calcium:**
Calcium is determined by EDTA titrimetric method.
EDTA+C\text{a}^{2+} \rightarrow \text{EDTA(Ca)}_2

1.2.2.10 Water quality standard:
International standards for drinking water were first published by WHO in 1985, then have been revised and reissued in a new form in 1993 and entitled as (Guide lines for drinking water quality). Table (1.3) shows WHO permissible values for drinking water.

**Table (1.3) WHO permissible values for drinking water 1993**

<table>
<thead>
<tr>
<th>No</th>
<th>Characteristic</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Hardness</td>
<td>500 mg/L as CaCo3</td>
</tr>
<tr>
<td>2</td>
<td>PH</td>
<td>6.5 – 8.5</td>
</tr>
<tr>
<td>3</td>
<td>Sodium</td>
<td>200 mg/L</td>
</tr>
<tr>
<td>4</td>
<td>Potassium</td>
<td>10 mg/L</td>
</tr>
<tr>
<td>5</td>
<td>Calcium</td>
<td>200 mg/L</td>
</tr>
<tr>
<td>6</td>
<td>TDS</td>
<td>1000 mg/L</td>
</tr>
<tr>
<td>7</td>
<td>Sulphate</td>
<td>400 mg/L</td>
</tr>
<tr>
<td>8</td>
<td>Chloride</td>
<td>250 mg/L</td>
</tr>
</tbody>
</table>

WHO (1993), Amman.
1.3 The objective of the study:

The aim of this study is to determine quantitatively some physical and chemical parameters namely pH, EC, TDS, hardness, Chloride, Calcium, Sulphate, Carbonate, Bicarbonate, Potassium and Sodium of wells water in Sennar city and compare the results with those recommended by WHO.

The analysis is carried out using simple analytical methods, depending on the availability of chemicals and equipment.
Chapter Two
Materials and Methods

In this section, samples collection and the chemicals used will be described.

2.1 Materials:

2.1.1 Water samples:

In this study six samples of drinking water were collected from six different wells in different places of the Sennar city.

Table (2.1): The dates of sample collection

<table>
<thead>
<tr>
<th>Samples (No)</th>
<th>Samples type</th>
<th>Date of collection</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Well (Kaboosh)</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>Well (Rahhal)</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>Well (Elabasia)</td>
<td>21/1/2013</td>
</tr>
<tr>
<td>D</td>
<td>Well (Elmazad 39)</td>
<td></td>
</tr>
<tr>
<td>E</td>
<td>Well (Elthwra)</td>
<td></td>
</tr>
<tr>
<td>F</td>
<td>Well (West Elgalaa)</td>
<td></td>
</tr>
</tbody>
</table>

2.1.2 Chemicals:

- Ammonia solution (SP.gr 0.91 g/ml .M.wt.17.01) assay 25%.
- Ammonium chloride G.P.R. England, assay 99.5%.
- Ethylene Di amine Tetra Acidic acid Di Sodium salt EDTA G.R (EDTA Sodium) $C_{10}H_{14}N_2O_8\cdot2H_2O$. (minimum assay, 99%)
- Eriochrome black T Indicator.
- Hydrochloric acid (SP.gr (1.18) M. wt (36.46) (35.4%).
- Barium chloride (BaCl$_2$).G.P.R. Assay 99.0%.
- Potassium chromate (K$_2$CrO$_4$).min assay 99.5% G.R.
- Silver nitrate (AgNO$_3$) M.wt 169.871.
- Phenolphthalein indictor assay (99%).
• Methyl Orange indicator. pH range 2.8 to 4.6 Red to Yellow.
• Sodium hydroxide pellets A.R, M.wt 40.00(99%).
• Murexide (Ammonium purpurate) indicator powder.
• Sodium chloride A.R (99.5%).
• Potassium chloride A.R (99.55%).
• Buffer of pH(3,7,10) buffer tablets of pH 3,7 and 10.

2.1.3 Apparatus used in analyses:
- Sets of titrations.
- Flame photometer (CORNING 400).
- Digital balance (YP202N Electronic Blance)
- pH meter (PHSJ-HA).
- Conductivity meter (Model DDs–IID).
- Fast TDS meter.

2.1.4 Reagents:

2.1.4.1 Hydrochloric acid (1:1)

2.1.5 Preparation of standards:

1. Standard buffer solution of pH 3,7 and 10:
   Buffer tablets of pH 3, 7 and 10 were dissolved and diluted to 100 ml with distilled water.

2. Ammonia buffer solution (pH:10).
   16.9 g ammonium chloride (NH₄CL) were added to 143 ml concentrated ammonium hydroxide (NH₄OH) and diluted to 250 ml with distilled water.

3. standard EDTA titrant (0.01 M):
   3.72 g of disodium EDTA salt (Na₂ H₂ C₁₀ H₁₄ O₈ N₂ 2H₂O) were dissolved in distilled water and diluted to 1 liter.

4. Eriochrome black T indicator (solid):
   1 g Eriochrome black T indictors was mixed with 10 g potassium nitrate.
5. Barium chloride (BaCl\(_2\)) solution 10%:  
10g of A.R BaCl\(_2\) 2H\(_2\)O were dissolved in distilled water and diluted to 100 ml.

6. Potassium chromate indicator (5%): 5.0 g of A.R K\(_2\)CrO\(_4\) were dissolved in about 20ml distilled water few drops of standard silver nitrate Ag NO\(_3\) were added till red precipitate was formed in solution, then was filtered and the filtrate was diluted to 100 ml with distilled water.

7. Silver nitrate titrant (0.014 M): 2.396g AgNO\(_3\) were dissolved in distilled water and diluted to 1 liter ; the resulting solution was stored in a dark bottle.

8. Phenolphthalein indicator solution (0.5%): 
0.5g phenolphthalein were dissolved in 50 ml 95% ethanol and diluted to 100 ml, with distilled water.

9. Methyl orange indicator solution (1%): 1 g methyl orange powder was dissolved in 10 ml ethanol and dilute with distilled water to 100 ml.

10. Hydrochloric acid (0.05 M): 4.2 ml Concentrated HCL were diluted to 1000 ml with distilled water.

11. Stock potassium solution(1000 ppm K): 1.9078 g of A.R KCL were dissolved in distilled water and diluted to 1000 ml to give 1000 ppm K.

12. Standard potassium solution: Stock potassium solution was diluted with distilled water to produce standard potassium solutions ranging from 4 to 20 ppm k\(^+\).

13. Stock Sodium solution (1000 ppm Na): 2.54mg of dried Sodium Chloride NaCl were dissolved in distilled water and diluted to 1000 ml to give 1000 ppm Na\(^+\).
14. Standard Sodium solutions: Stock sodium solution was diluted with distilled water to produce standard sodium solutions ranging from 0 to 50 ppm.

15. Sodium Hydroxide (1M): 4 g of A. R NaOH were dissolved in distilled water and diluted to 100 ml.

16. Murexide (Ammonium puprate, indicator, powder). Tablet weighed (0.05 g).

17. Potassium Chloride Solution (0.01M):

0.7455 g of A.R KCL were dissolved and diluted to 1 liter with distilled water to make standard reference solution.

2.2 Methods:

2.2.1 Determination of pH:

pH value was measured by pH meter. The meter was calibrated by standard buffer solution of pH 3.7 and 10 at 26°C, the pH value of samples were recorded.

2.2.2. Electrical conductivity (EC):

Electrical conductivity was measured by conductivity meter(model DDS-11D). Electrolytic conductivity measuring set was used with specific conductance cell. It was calibrated with 0.01 KCL (already prepared).

2.2.3 Determination of (TDS):

TDS was measured by TDS meter. The electrode of TDS meter was washed using distill water then water samples were transferred to container and the TDS was measured directly.

2.2.4 Determination of Chloride:

This method was used due to availability of apparatus and chemicals (see p5).

50 ml of each sample were placed in 250 ml conical flask, 1 ml of \( \text{K}_2\text{CrO}_4 \) indicator was added and the solution was then titrated with
(0.014M) Ag NO₃ solution (AgNO₃ solution standardized by Mohr method using standard KCL solution) until a pinkish yellow precipitate was produced. The distilled water used as blank was treated in the same manner (Vogel's, 1978).

**Calculation:**

\[ \text{CL}^- \text{ mg/L} = \frac{(A - B) \times M \times 35.5 \times 1000}{V} \]

Where:

- \( A \equiv \text{ml of Ag NO}_3 \text{ required for the sample.} \)
- \( B \equiv \text{ml of titrant for the blank} \)
- \( M \equiv \text{morality of Ag NO}_3 \text{ solution} \)
- \( V \equiv \text{ml sample} \)

---

**2.2.5. Determination of Hardness:**

This method was used due to the availability of apparatus and chemicals. (See p7).

EDTA titrimetric method was used as described in page 7, 1 ml Ammonia buffer solution and about 30 mg of Eriochrome black indicator were added to 50 ml water sample in a 250 ml conical flask. The solution was then titrated with 0.01m EDTA solution until colour changes from wine red to blue end point (Vogel's 1978).

**Calculation:**

Hardness as mg/L CaCO₃ = \( \frac{A \times B \times 1000}{V} \) (general formula)

Where:

- \( A \equiv \text{ml of EDTA required for titration.} \)
- \( B \equiv \text{ml of CaCO3 equivalent to 1 ml EDTA titrant.} \)
V ≡ ml of sample

\[ \text{Hardness} = \frac{V \times 0.01 \times 100 \times 1000}{50} \]

Therefore hardness: 20 v ppm

V ≡ volume of EDTA required for titration.

2.2.6 Determination of sulphate:

50 ml of water samples were placed in a 250 ml beaker. The pH was adjusted with HCL (1:1) to 4 -5 using pH meter. The solution was then heated to boiling. Warm barium chloride (BaCL₂) solution was added slowly. No apparent turbidity is shown indicating of no or small amount of SO₄²⁻ (Vogel's, 1978).

2.2.7 Determination of carbonate and bicarbonate:

To 50 ml water sample few drops of phenolphthalein solution were added, and the solution was titrated with 0.05 M HCL. The burette reading (say x) was recorded. Few drops Methyl orange indicator were added to titration flask and titration was continued tell the end point when the color change from yellow to red (burette reading y).

**Calculation:**

X ≡ volume of acid ≡ ½ carbonate

Therefore

\[ 2x = \text{volume of acid required to titrate all the carbonate} \]

In 50ml of sample.

Y ≡ volume of acid = all carbonate + all bicarbonate

\[ Y - 2X = \text{volume of acid required to titrate all the bicarbonate in 50 ml sample.} \]

The result were expressed as mg/L
Therefore:

\[
\text{CO}_3^{2-} \text{ mg/L} = \frac{2X}{0.05 \times V \times 60 \times 1000} \times \frac{50 \times 2}{50} \\
\]

Where:

- \( V \) = volume of acid – required titrate all carbonate in 50 ml sample.
- \( 60 \) = The molecular weight of the carbonate.
- \( \text{HCO}_3^- \text{ mg/L} = \frac{0.05 \times (Y - 2X) \times 61 \times 1000}{50} \)
  
  \( 61 \) = The molecular weight of bicarbonate.

**2.2.8 Determination of Calcium:**

This method was used due to the available apparatus and chemicals (see p10).

50 ml water sample placed in 250 conical flask, 0.5 ml NaOH solution were added to get a pH of (12-13) and the solution was stirred. 0.2 gm of murexide indicator was added, while stirring and 0.01 ml EDTA solution was added slowly till the end point reached the colour change from pink to purple.

**Calculation:**

\[
\text{Ca}^{+2} \text{ mg/L} = \frac{A \times B \times M \times 40 \times 1000}{\text{Ml of sample}} \\
\]

Where:

- \( A \equiv \text{ml of titrant for the sample} \)
- \( B \equiv \text{mg CaCO}_3 \text{ equivalent to 1.00 ml. EDTA titrant} \)
- \( M \equiv \text{morality of EDTA} \)
- \( 40 \equiv \text{calcium molecular weight} \).
2.2.9 Determination of Sodium:

Form the stock solution 1000 ppm Na\(^+\), 2ml, 4ml, 6ml, 8ml, 10ml were transferred to 100 ml conical flasks and diluted to the mark with the distilled water to give 20, 40, 60, 80 and 100 ppm Na. The flame photometer was then used to read the emission intensities of the standards and the samples.

The calibration curve was then constructed and from which the concentration of Na in the water samples were determined. Fig (1) shows the Calibration curve for Na

2.2.10. Determination of Potassium:

From the stock solution containing 1000 ppm K\(^+\), 20 ml were transferred to 100 ml flask and diluted to the mark with distilled water to give (200 ppm K). 2 ml, 4 ml, 6 ml, 8 ml, 10 ml from this solution, were transferred to 100 ml flasks and diluted to the mark with stilled water to give 4, 8, 12, 16 and 20 ppm K.

The flame photometer was then used to read the emission intensities of the standards and the samples.

The calibration curve was then constructed and from which the concentration of K in the water samples were determined Fig (2) shows the calibration curve for K.
Chapter three
Result and discussion

3.1 Results:

3.1.1 Result of pH, EC and TDs

Table (3.1) The pH, electrical conductivity (EC) and total dissolved solid (TDs).

<table>
<thead>
<tr>
<th>Sample No</th>
<th>pH</th>
<th>TDS in ppm (mg/L)</th>
<th>Ec µs/cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>8.3</td>
<td>200</td>
<td>385</td>
</tr>
<tr>
<td>B</td>
<td>8.2</td>
<td>300</td>
<td>511</td>
</tr>
<tr>
<td>C</td>
<td>8.1</td>
<td>370</td>
<td>663</td>
</tr>
<tr>
<td>D</td>
<td>8.1</td>
<td>300</td>
<td>516</td>
</tr>
<tr>
<td>E</td>
<td>8.4</td>
<td>490</td>
<td>845</td>
</tr>
<tr>
<td>F</td>
<td>8.4</td>
<td>650</td>
<td>880</td>
</tr>
</tbody>
</table>

3.1.1.1 pH value:
The results of table (3.1) shows that the pH varies between (8.1 to 8.4) which indicated that all samples fall in the alkaline side. Therefore the pH values obtained were within the WHO standard summarized in table (1.3).

3.1.1.2 Electrical conductivity (EC)
The result of electrical conductivity in µ mohs/cm in table (3.1) were in agreement with the value reported by WHO standards.

3.1.1.3 Total dissolved solids (TDS).
Table (3.1) shows that values of TDS for the samples are within the permissible range of WHO in table (1.3)
3.1.2 Results of concentration of dissolved species:

Table (3.2) chloride, sulphate, carbonate, bicarbonate and hardness.

<table>
<thead>
<tr>
<th>Sample No</th>
<th>Cl⁻ in ppm</th>
<th>SO₄²⁻ in ppm</th>
<th>CO₃²⁻ in ppm</th>
<th>HCO₃⁻ in ppm</th>
<th>Hardness in ppm</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>14.91</td>
<td>Nil</td>
<td>18</td>
<td>237.9</td>
<td>180</td>
</tr>
<tr>
<td>B</td>
<td>29.82</td>
<td>Nil</td>
<td>18</td>
<td>311.1</td>
<td>228</td>
</tr>
<tr>
<td>C</td>
<td>28.82</td>
<td>Nil</td>
<td>30</td>
<td>396.5</td>
<td>264</td>
</tr>
<tr>
<td>D</td>
<td>25.84</td>
<td>Nil</td>
<td>12</td>
<td>359.9</td>
<td>226</td>
</tr>
<tr>
<td>E</td>
<td>63.61</td>
<td>0.7</td>
<td>18</td>
<td>542.9</td>
<td>264</td>
</tr>
<tr>
<td>F</td>
<td>67.59</td>
<td>0.5</td>
<td>30</td>
<td>573.4</td>
<td>350</td>
</tr>
</tbody>
</table>

3.1.2.1 Chloride:

The results of chloride concentration summarized in table (3.2) show that the sample have chloride content within permissible range reported by the WHO table (1.3). Sample E and F have higher limits values of chloride compared with the samples A, B, C and D.

3.1.2.2 Sulphate:

Table (3.2) shows that the concentration of sulphate in samples AB,C,D are less than 0.1 ppm, but sample E (0.7 ppm) sample F (0.5ppm). Therefore all samples are within permissible WHO values.

3.1.2.3 Carbonate and bicarbonate:

As an observation from carbonate and bicarbonate results obtained and listed in table (3.2), the carbonate values were low when compared with concentration values of bicarbonate this may be due to the conversion of carbonate to bicarbonate.

3.1.2.4 Hardness:

The results obtained for hardness in table (3.2) show that all samples were within permissible WHO values and sample (A) is classified as moderately hard where sample (B,C,D,E) are hard and
sample(F) is very hard, this is according to classification of water on the basis of hardness (table 2).

3.1.3 Results of cation concentration:

Table (3.3) Sodium, potassium, calcium.

<table>
<thead>
<tr>
<th>Sample No</th>
<th>Sodium Na(^+) in ppm</th>
<th>Potassium in ppm</th>
<th>Calcium in ppm</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>45</td>
<td>1.2</td>
<td>80</td>
</tr>
<tr>
<td>B</td>
<td>70</td>
<td>2.5</td>
<td>45.6</td>
</tr>
<tr>
<td>C</td>
<td>96</td>
<td>2.5</td>
<td>40</td>
</tr>
<tr>
<td>D</td>
<td>59</td>
<td>1.8</td>
<td>61.6</td>
</tr>
<tr>
<td>E</td>
<td>192</td>
<td>2.5</td>
<td>80</td>
</tr>
<tr>
<td>F</td>
<td>184</td>
<td>2.6</td>
<td>80</td>
</tr>
</tbody>
</table>

3.1.3.1 Sodium and potassium:

The concentration of the two cations (Na\(^+\) and K\(^+\)) in the samples were obtained from calibration curves shown in fig (1) and fig(2). The results are summarized in table 3.1.3. All the samples have sodium and potassium concentration within permissible limits of WHO (table1.3). But the values of sodium concentration are higher compared to the value of potassium concentration in all the sample.

3.1.3.2 Calcium:

The guide of calcium reported by the WHO is (200ppm) as in table (1.3) and therefore all samples showed values which were in agreement with the value of WHO.
Fig. (1) Curve of Sodium

Fig. (2) Curve of Potassium
Conclusion:

The findings of the study can be concluded in the following:

All the samples have no hardness problem, neither temporary nor permanent.

All water samples showed pH values that are within the permissible level as reported by WHO.

The TDS value of all the samples were within the permissible level stated by WHO.

The concentrations of anions and cations are in agreement with that of WHO standards.

Therefore all water samples were suitable for human and animal use.

Recommendations:

Chemical analysis for sodium and potassium, were not available in water corporation in Sennar city, because of the lack of instruments and reagents, qualified chemical laboratories are needed.

*Regular testing and adopting practice to prevent contamination can help ensure that well supplies are with good drinking water.

*Since many contaminates are colourless and odourless testing is the only way to determine whether well water is safe to drink or not.

*Setting laws to prevent digging deep sapting tanks.
References


