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Determination and Removal of Hardness of Water Sample at Nagaur, Rajasthan, India

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***Abstract:** Drinking water rich in calcium and magnesium leads to problems in normal usage and industrial processes by causing blockages in pipes and producing subpar soap performance. One of this work's objectives is to explain methods of measuring and extracting water hardness. The water samples underwent hardness measurement through a well-known EDTA titration method. Our work investigated three methods to minimize hardness such as ion exchange and lime softening and reverse osmosis. The study demonstrated that reverse osmosis delivered the best performance regarding hardness elimination though it needs significant energy consumption to operate. Most treatments used an ion exchange process which proved cost-effective yet lime softening provided limited effectiveness across different circumstances. Research findings let us establish better approaches to handle and improve water quality depending on its end-purpose.*
***Keywords:** Water Hardness, EDTA Titration, Ion Exchange, Lime Softening, Reverse Osmosis*

I. INTRODUCTION

Water hardness exists as a widespread issue from minerals such as calcium and magnesium dissolved in water supplies. The presence of these minerals leads to daily problems such as ineffective soap use and pipe and water heater scale buildup. Multiple industrial processes containing water face permanent damage when hard water enters their systems because it operates as a destructive agent during both short and extended periods of time.

The water hardness measurement depends on assessing the calcium and magnesium ion contents within the water substance. This paper addresses two essential objectives regarding water hardness: measurement technique selection and development methods for water hardness reduction.

This paper evaluates hardness measurement by the EDTA titration method while assessing hardness reduction methods which comprise boiling together with ion exchange and lime softening and reverse osmosis. The knowledge of these methods enables better water quality management and safe application usages.

II. LITERATURE REVIEW

The water quality characteristic of hardness has been extensively researched for extended periods because it significantly affects residential and manufacturing systems. The primary elemental causes of hard water involve calcium ion (Ca^{2+}) and magnesium ion (Mg^{2+}) that eventually produce salts including calcium carbonate ($CaCO_3$) and magnesium carbonate ($MgCO_3$). The presence of these salts results in pipe clogging and water-hardening that limits appliance efficiency at homes and it creates operational difficulties for water-dependent industrial systems including boilers and cooling systems. The knowledge about water hardness origins and both detection methods and elimination approaches becomes vital for handling these problems effectively.

A. Causes of Water Hardness are

Water hardness develops naturally from mineral substances like calcium and magnesium which dissolve in soil then rock formations while water passes through them. The water dissolves minerals after it interacts with limestone and gypsum as well as other calcium and magnesium-bearing rocks. Wells draw groundwater that typically shows higher mineral concentrations compared to surface-supplied rivers and lakes which tend to be less hard. The levels of water hardness differ considerably based on three factors: the geographic area where water comes from and what kind of rocks are present within it and which water source gets collected first.

The research done by Srinivas et al. (2015) outlines a classification system for water hardness which relies on calculating calcium and magnesium concentrations to determine *slight hard (0–60 mg/L), moderate hard (61–120 mg/L)* and *hard (121–180 mg/L)* and *very hard (>180 mg/L).* Water hardness classification through this method allows both water severity assessment and selection of proper treatment approaches.

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B. Effects of Water Hardness

Hard water leads to several problems within domestic residences together with agricultural operations and industrial facilities. The presence of calcium and magnesium ions in domestic settings reduces the performance of soap products leading to soap scum formation. The formation of soap scum along with higher detergent usage becomes more probable when hard water substances and particles are present. The buildup of mineral residues within both pipes and water heaters shortens their operational effectiveness along with decreasing their useful life. Boiler and cooling systems experience increased operational costs because scale buildup requires additional energy consumption for reaching necessary heating temperatures according to *Bennet and Smith (2017).*

Scaling occurs in industrial facilities throughout heat exchangers along with pipes and boilers because of hardness. The impacted surfaces gradually experience metal corrosion which causes additional operational issues leading to possible device failures. Heat exchange rates in power plants decrease because of scale buildup resulting in boiler damage alongside higher fuel usage. Water hardness creates problems for textile industries and food processors and paper manufacturers because it diminishes cleanliness in their production water which damages products and hinders machine functioning.

III. METHODOLOGY

A. EDTA

A widely employed analytical method to test water hardness uses the EDTA method (Ethylene Diamine Tetra acetic Acid method). The main cause of water hardness comes from dissolved calcium (Ca^{2+}) and magnesium (Mg^{2+}) ions existing in the water. The metal ions bond to form salts like calcium carbonate alongside magnesium sulfate which make up the overall water hardness. EDTA quantifies water hardness through its ability to form stable complexes with metal ions therefore allowing the detection of water hardness. The procedure provides accuracy through versatility when measuring water hardness across various examples of water samples.

Procedure for the EDTA complexometric titration method to determine water hardness:

1) The water sample requires preparation by collecting a specific volume of 20 ml. The water's hardness will determine whether you need to prepare it with distilled water.
2) *Addition of Buffer Solution:* Several drops of ammonia buffer solution prepared from ammonium chloride and ammonium hydroxide should be added to the sample. The solution reaches a pH value of 10 through the addition of an ammonia buffer which enables EDTA to properly attach to calcium and magnesium ions.
3) *Addition of Indicator:* You should add several drops of Eriochrome Black T indicator to the water sample. When calcium and magnesium ions exist in the sample the solution changes to red.
4) *Titration setup:* Fill a clean burette with a standardized EDTA solution.
5) *Titration Initiation*: A safety-foam-barrier covers the burette containing EDTA solution while the analyst slowly pours it into the flask through constant stirring of the solution. When EDTA enters the solution the calcium and magnesium ions become bound with it. The sample colour transformation will proceed from red through a range of colours until it becomes blue during the titration process. The red color indicates the presence of free calcium and magnesium ions in the solution, while the blue color indicates that all the metal ions have reacted with the EDTA.
6) *End Point Detection:* We can determine the titration completion through the red to blue color transformation. The solution turns blue because all magnesium and calcium ions have successfully reacted with EDTA. Thus, indicating no metallic ions remain available within the solution.
7) *Calculation:* The amount of EDTA used is noted, and from this, the hardness of the water is calculated using the formula:

   Hardness (mg/L as $CaCO_3$) = (volume of EDTA solution × normality (concentration) of the EDTA solution × Equivalent weight of $CaCO_3$) / volume of the water sample

8) Repeating the *EDTA titration* multiple times and taking the average of the readings is a common practice to improve the accuracy and reliability of the test results.

$$Average\ Hardness = \frac{Sum\ of\ all\ hardness\ values}{No.of\ tests}$$

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Fig. 1. Titration flask filled with the reactants

B. Readings

Volume of Std. hard water sample (ml)	Burette Reading (ml)	Volume of EDTA Solution (ml)	Concordant Reading (ml)
20	27.5	5	
20	27.5	5	
20	25	5	27.5

1) Boiling Method is used for Removing Temporary Hardness

The boiling method is a simple and effective way to reduce temporary hardness in water, which is primarily caused by the presence of bicarbonate ions $(HCO_3{}^-)$ of calcium (Ca^{2+}) and magnesium (Mg^{2+}). The reactions that occur are:

$$Ca(HCO_3)_2 \rightarrow CaCO_3 + CO_2 + H_2O$$
$$Mg(HCO_3)_2 \rightarrow MgCO_3 + CO_2 + H_2O$$

2) Washing Soda Method is used for Removing Permanent Hardness

Sodium carbonate (Na_2CO_3) is added to the hard water. Washing soda reacts with the calcium and magnesium ions in the water to form insoluble precipitates, removing them from the solution.

Chemical Reactions: When sodium carbonate is added to water, it reacts with calcium ions (Ca^{2+}) and magnesium ions (Mg^{2+}) to form calcium carbonate $(CaCO_3)$ and magnesium carbonate $(MgCO_3)$, both of which are *insoluble in water* and precipitate out.

$$Ca2 + +Na2CO3 \rightarrow CaCO3(s) + 2Na +$$
$$Mg_2^+ + Na_2CO_3 \rightarrow MgCO3(s) + 2Na^+$$

Removal of Hardness: By forming these insoluble precipitates, washing soda effectively *removes calcium* and *magnesium ions* from the water, thus softening it. This reduces the hardness of the water.

C. Hardness Test of Water: pH and Conductivity

The examination of water hardness requires evaluation of pH and conductivity together because these measurements impact hardness measurements while revealing extra information about water properties.

$The\ pH\ of\ water\ sample\ before\ treatment = 11$ and $conductivity = 18.42\ (\mu S/cm)$

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Fig. 2. Weighing scale

IV. RESULTS

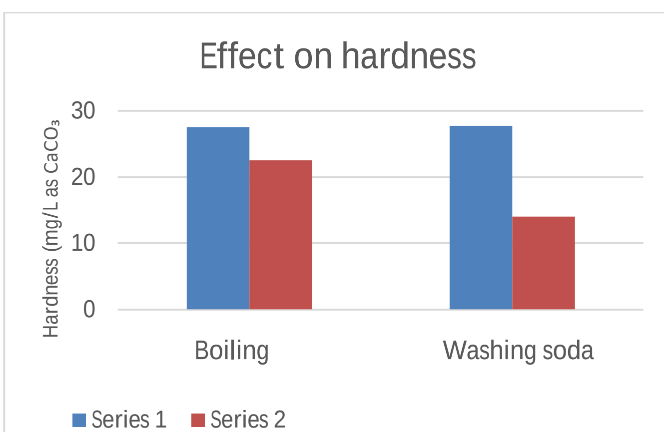
A. Water Hardness after Boiling

Volume of Std. hard water sample (ml)	Burette Reading (ml)	Volume of EDTA Solution (ml)	Concordant Reading (ml
20	23	5	
20	22.5	5	
20	22.5	5	22.5

B. Water Hardness after Washing Soda Treatment

Volume of Std. hard water sample (ml)	Burette Reading (ml)	Volume of EDTA Solution (ml)	Concordant Reading (ml
20	14.5	5	14
20	14	5	
20	14	5	

C. Graph



Series 1= Before testing
Series 2= After testing

D. pH and Conductivity

The pH of water sample after treatment = 9.5 and the conductivity is 14.82 (μS/cm)

V. FUTURE SCOPE

Future solutions for solving water hardness in Nagaur alongside affected regions require technology enhancement coupled with new method innovation and complete water management system integration. The united emphasis on sustainability alongside cost-efficiency alongside scalability characteristics presents a powerful opportunity to improve water quality together with decreasing environmental effects of water treatment methods and enhance public health throughout these communities. The solution of long-term water hardness problems requires sustained coordination between technological advancements and policy development together with broad public understanding.

VI. CONCLUSION

The study proves the EDTA method represents an accurate and effective technique to measure water hardness by quantifying calcium and magnesium levels. Testing of Nagaur water revealed that its levels reach the definition of very hard water which presents problems in domestic and industrial applications.

The washing soda (sodium carbonate) process demonstrates excellence as an affordable option for decreasing water hardness levels. The possession of approximately 80% removal efficiency makes washing soda function as an affordable and straightforward method to treat water hardness in areas marked by elevated hardness conditions including Nagaur.

Research should investigate how to implement the right amount of washing soda for specific water hardness scenarios while analysing sustainable large-scale application of wash soda as a water treatment method. The outcomes of researching the environmental effects of washing soda waste disposal should be examined in more detail.

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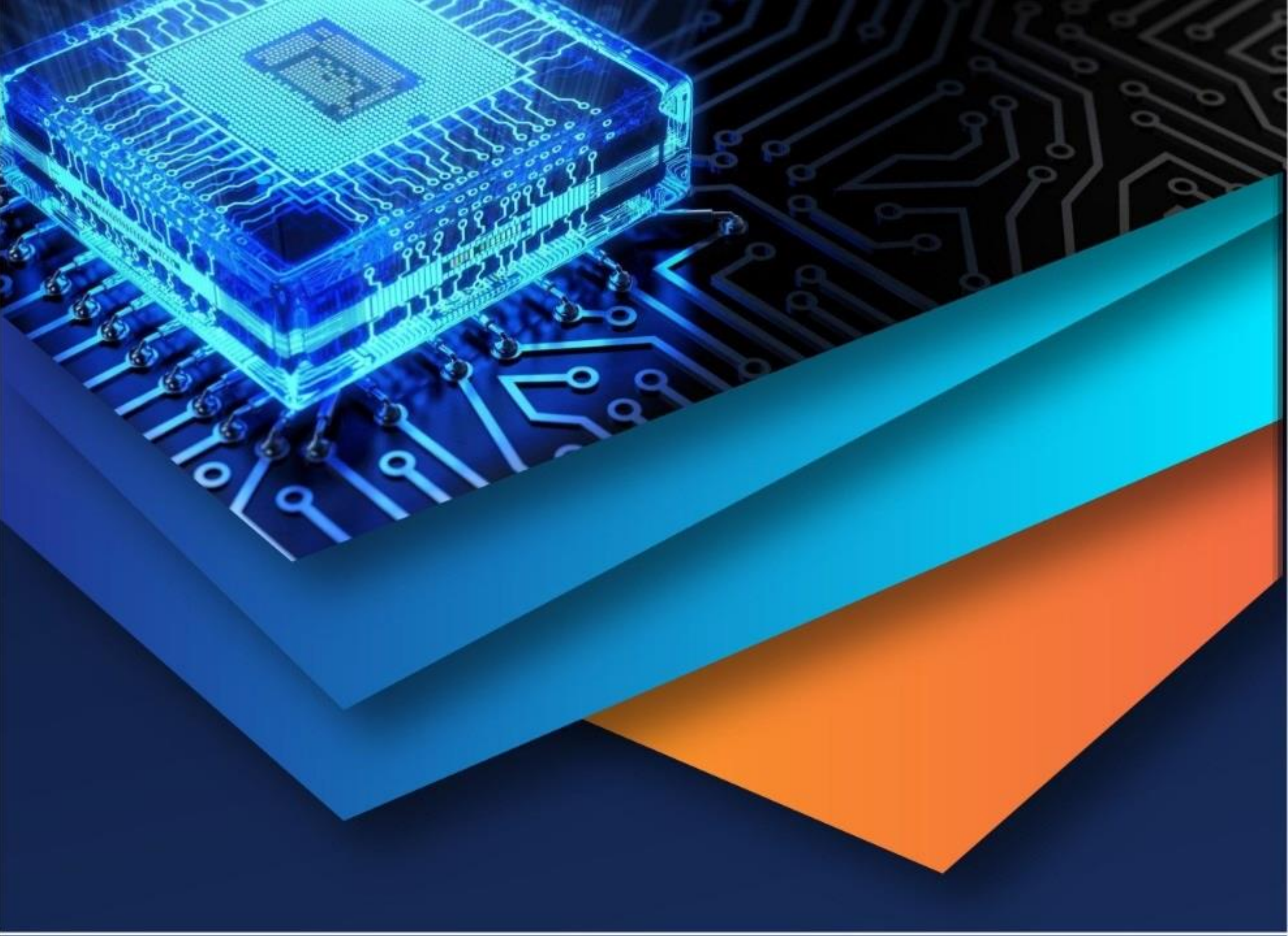

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