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# Assessing the Impact of Water Softening Techniques on Hardness and TDS levels in different Water Sources

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**Abstract—***Water hardness results from calcium and magnesium, which can cause scaling and other issues in industrial processes. In the present study, the effectiveness of two commonly used techniques, magnetic water conditioning and ion exchange, is assessed for reducing water hardness and total dissolved solids (TDS) content. Borewell and industrial water were examined. The results showed that ion exchange treatment reduced hardness and TDS levels by 9-23% and 7-12%, respectively. Similarly, magnetic water conditioning decreased hardness and TDS levels by 3-7% and 1-3%, respectively. The findings suggest that ion exchange treatment and magnetic water conditioning effectively reduce water hardness and TDS levels. Ion exchange treatment reduces water hardness and TDS levels more effectively than magnetic water conditioning. However, magnetic water conditioning provides an environmentally sustainable approach without using chemicals.*

**Keywords:** *Hardness, Total dissolved solids, Softener, Ion exchange, Magnetic water conditioning*

## Introduction

Water softening removes or reduces the amount of minerals, such as calcium and magnesium, from hard water. Hard water can cause problems such as scaling, soap scum build-up, and appliance damage. Two standard methods for water softening are ion exchange and magnetic water conditioning [1]. A water softener is usually required from a tank filled with resin beads charged with salt ions. The calcium and magnesium ions in hard water are switched out for sodium ions as they travel through the resin bed, softening the water. The resin beads ultimately get saturated with calcium and magnesium ions, and to regain their capacity to soften water, they must be regenerated with a brine solution (often salt). Magnetic water conditioning, which softens hard water via a magnetic field, is another technique [2]. According to the theory underlying this technique, the magnetic field alters the structure of the mineral ions in the water, making scale and other deposits less likely to develop. However, scientists continue to disagree on the usefulness of magnetic water conditioners. Water softening is critical in raising water calibre in households and workplaces. While magnetic water conditioning is still an unproven option, ion exchange water softening is a tried-and-true technique frequently utilised. One of the most typical issues with water quality that many households have is water hardness, which is removed by a water softener.

Hard water dries out hair and skin, damages appliances, and creates a film of soap scum all over bathrooms and kitchens. Water softeners are essential since hard water is used by over 85% of Americans for bathing, cleaning, and cooking [3]. A water softener saves you from spending many hours cleaning off the soapy residue and repairing prematurely damaged water heaters and scaly tap heads. Investing in water softeners may save time, money, and effort. It also safeguards the house and other property. A whole-house filtering device called a water softener uses an ion exchange mechanism to remove the calcium and magnesium minerals that cause water to become hard. Water with a high concentration of dissolved minerals, such as calcium and magnesium, is hard water. Soft water contains few of these minerals. Many problems can be brought on by hard water, including clogged pipes, decreased efficacy of soaps and detergents, and the build-up of limescale on appliances[4]. Consequently, it is crucial to turn hard water into soft water.

A type of water treatment device known as an ion exchange water softener eliminates hard minerals from water by exchanging them with sodium ions. The procedure involves running water over a resin bed filled with microscopic resin beads charged with sodium ions. Hard minerals are drawn to the resin beads when the water passes through the bed, taking the place of the sodium ions discharged into the water. It is a typical method for softening water. It involves putting sodium ion-filled resin through hard water. The resin bed efficiently softens the water by exchanging the calcium and magnesium ions with sodium ions. Soft water is the resultant water [5]. A device known as a magnetic water conditioner employs magnets to change the physical characteristics of water. The idea behind magnetic water treatment is that by changing the structure of the minerals and ions in the water, the magnetic field will lessen the production of deposits like limescale. It may result in better water flow, less frequent need for plumbing and appliance repair, and even better plant growth in agricultural settings [6]. Many magnetic water conditioners are available, from tiny, straightforward devices that attach to pipes or faucets to more substantial systems intended for commercial or industrial use.

**Literature Survey**

The "ion exchange water softening" method removes hardness from water by swapping out calcium and magnesium ions for sodium ions, which do not produce scale deposits. The ion exchange water softening efficiency depends on various variables such as water quality, cost-effectiveness, and environmental impact [7]. The removal of water hardness by ion exchange water softening was successful. However, it also increases the salt concentration, which may not be suitable for people following a low-sodium diet. However, this method removes impurities like lead, copper, and iron from water and heavy metals like lead, cadmium, and chromium. It has also been discovered to be an economical and ecologically responsible method for softening and lowering water hardness by up to 97% [8]. Ion exchange softener regenerate cycles are influenced by water flow rate, resin type, and water hardness. According to the water hardness and resin type, it was discovered that the frequency of ion exchange softener regeneration varied from once every five days to once every 20 days [9]. Water quality: By reducing hardness, which may lead to scale and corrosion in pipes and appliances, ion exchange softeners have been found to enhance the overall quality of water.

It was discovered that ion exchange softeners produced considerable savings in terms of decreased maintenance costs and extended equipment lifespan. During the regeneration process, ion exchange softeners produce a brine waste stream that, if improperly disposed of, can have adverse environmental effects. However, several studies have indicated that by employing effective regeneration strategies and appropriate disposal approaches, the environmental impact of ion exchange softeners may be reduced [10].

Devices called magnetic water conditioners claim that they may lessen the impacts of hard water by employing magnetic fields to change the characteristics of the water's minerals. There is substantial disagreement in the research on magnetic water conditioners. However, some studies show they can help decrease scaling and other issues related to hard water; others have found no appreciable results. One study looked at how a magnetic water conditioner affected water's chemical and physical characteristics [11]. According to the study, the magnetic fields generated by the apparatus did change the structure of water molecules and shrink mineral clusters, which may lessen the accumulation of scale in pipes and appliances [12]. Another examined a variety of magnetic water conditioners in various settings and discovered no significant modifications to the water's chemical or physical composition. Numerous investigations of magnetic water conditioners concluded that, despite some promising results, there was insufficient data to justify its usage as a dependable water treatment technique [13]. Overall, additional study is required to fully understand the possible advantages and drawbacks of magnetic water conditioners, even though there is some evidence that they may be beneficial in decreasing scaling and other issues related to hard water. Studies on the efficiency of magnetic water conditioners in lowering water hardness have shown conflicting findings. While some studies revealed no appreciable change compared to untreated water, some have shown considerable decreases in water hardness. According to research, magnetic water conditioning can reduce the hardness of the water by up to 70%. Magnetic water conditioners' working principle is not yet completely understood. According to specific research, the magnetic field changes the crystal structure of the water's minerals, reducing their propensity to stick to surfaces and create scale. Other research contends that the magnetic field has little to no impact on the water's mineral composition.

In comparison to conventional water softening techniques like ion exchange or chemical treatment, magnetic water conditioners are typically considered more economical. According to a study, the price of magnetic water conditioning is 50% less than that of ion exchange softening. Since they do not require chemicals or regeneration, magnetic water conditioners have been proposed as a more ecologically friendly alternative to conventional water softening techniques. More study is required in this area [14] because few studies have been done on magnetic water conditioners' effects on the environment. Magnetic water conditioners require less maintenance than conventional water softening techniques because they do not have moving components or need chemicals. To avoid accumulating dirt or other particles, they could need cleaning regularly.

**Experimental Methodology**

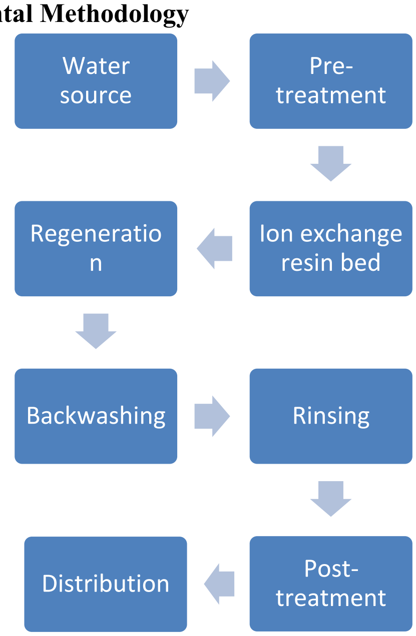


**Fig. 1 Flowchart for ion exchange treatment**

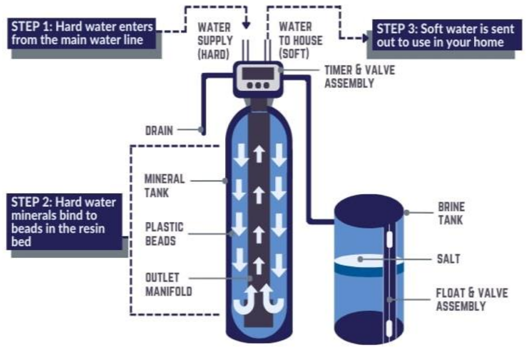


**Fig. 2 Ion Exchange process**

Water hardness-inducing ions like calcium and magnesium are exchanged for sodium ions using ion exchange water softeners. This is achieved by using a resin bed composed of tiny beads of a synthetic substance with a negative charge [15]. The ions that give water its hardness are drawn to the negatively charged resin beads as they flow through the resin bed and are replaced by sodium ions. There are multiple processes in the ion exchange process, including backwashing, regeneration, and rinsing. Backwashing cleans the resin bed's surface of any dirt or accumulation. Regeneration includes removing the accumulated hardness-causing ions and replacing them with sodium ions in the resin bed using a solution of sodium chloride (salt) and water. Rinsing is rinsing the resin bed with clean water to eliminate any pollutants or salt that may still be present [16]. Ion exchange water softeners have the benefit of constantly producing soft water while being excellent at eliminating the minerals that cause water to become hard. To ensure the resin bed is operating at its best, they need routine maintenance, such as adding salt and watching the regeneration cycle.

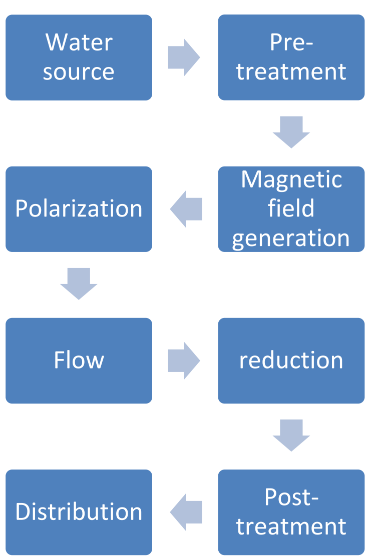


**Fig. 3 Flowchart for magnetic water conditioner**

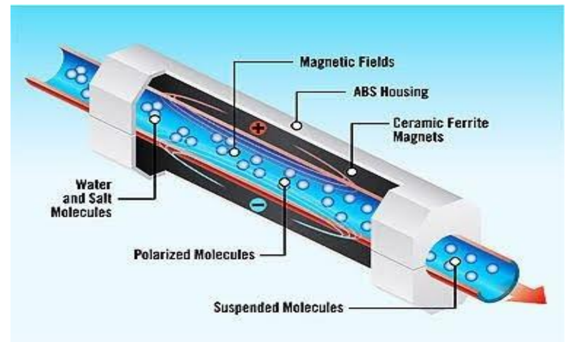


**Fig. 4 Magnetic water conditioner**

On the other hand, magnetic water conditioners function by exposing water to a magnetic field, modifying the water's physical and chemical characteristics. The alignment of the charged particles in the water due to the magnetic field might lessen the production of scale and other issues brought on by hard water. The placement of the device in the water supply line, often close to the point of entrance into a residence or business, is the mechanism for magnetic water conditioners. A magnetic field produced by a number of magnets or a single strong magnet is passed through by the water as it goes through the magnetic water conditioner. Hard water's mineral ions form smaller clusters or crystals in the magnetic field, less prone to stick to surfaces and accumulate scale [17]. Magnetic water conditioners have the benefit of being relatively minimal maintenance and not requiring the addition of chemicals or salt. Additionally, they leave all the minerals in the water suitable for human health. However, scientists continue to disagree on the usefulness of magnetic water conditioners.

**Results and Discussion**

**Table 1: Comparison of levels of hardness and TDS in borewell and Industrial water before and after ion exchange treatment**

| Water | Hardness (mg/L) | | TDS (ppm) | |
|---|---|---|---|---|
| Type | Before | After | Before | After |
| **Borewell** | 135 | 104 | 149 | 137 |
| **Industrial** | 160 | 129 | 156 | 144 |

Table 1 presents the hardness and TDS levels for borewell and industrial waters before and after ion exchange treatment. Both water samples showed higher levels of hardness and TDS before water softening treatment (ion exchange or magnetic water conditioning). Specifically, the borewell water had a pre-treatment hardness of 135 mg/L and TDS of 149 mg/L, which decreased to 104 mg/L (23% reduction) and 137 mg/L (8% reduction), respectively, after ion exchange treatment. On the other hand, the industrial water had a higher pre-treatment hardness of 160 mg/L and TDS of 156 mg/L, which decreased to 129 mg/L (19% reduction) and 144 mg/L (8% reduction), respectively, after treatment. These findings indicate that ion exchange treatment effectively reduced hardness and TDS levels in both water samples, with a percentage reduction ranging from 8-23%. The borewell water exhibited a more significant percentage reduction in both parameters. Lower levels of hardness and TDS can be beneficial in preventing scaling and other issues in industrial processes and improving the quality and taste of drinking water.

Table 2 shows the results of magnetic water conditioning on the same water samples. Magnetic water conditioning treatment decreases the hardness and TDS of borewell water to 126 mg/L and 147 ppm, respectively, reducing 6.7% hardness and 1.3% for TDS. Similarly, the hardness and TDS of the industrial water decreased to 149 mg/L and 153 ppm, respectively, after treatment. It represents a reduction of 6.9% for hardness and 2.9% for TDS. These results suggest that magnetic water conditioning effectively reduced hardness and TDS levels for both samples, with a greater percentage reduction observed in the borewell water. As a non-chemical alternative to conventional water treatment methods, magnetic water conditioning may provide a more sustainable option for reducing water hardness and TDS levels. In particular, for those who want to use fewer chemicals in their water treatment process, utilising magnetic fields can be a more eco-friendly solution to address hard water issues.

**Table 2: Comparison of levels of hardness and TDS in borewell and Industrial water before and after magnetic water conditioning.**

| Water Type | Hardness (mg/L) | | TDS (ppm) | |
|---|---|---|---|---|
| | Before | After | Before | After |
| **Borewell** | 135 | 126 | 149 | 147 |
| **Industrial** | 160 | 149 | 156 | 153 |

## Conclusion

The study investigated the effectiveness of water softening techniques, including ion exchange and magnetic water conditioning, for reducing water hardness and TDS levels in borewells and industrial waters. The results showed that both techniques reduce water hardness and TDS levels effectively. Ion exchange treatment demonstrated a more significant percentage reduction than magnetic water conditioning. The percentage reduction in hardness and TDS levels ranged from 9-23% and 7-12% for ion exchange treatment, while magnetic water conditioning reduced from 3-7% for hardness and 1-3% for hardness TDS. These findings suggest that ion exchange treatment is a more effective water treatment method in reducing both water parameters. However, magnetic water conditioning provides a non-chemical alternative to traditional water treatment methods and may be more environmentally sustainable. The use of these water treatment techniques can help prevent scaling and other issues in industrial processes and improve the overall quality of drinking water.

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