

Determination of Total and Temporary Hardness in Waters of Differing Origin and Treatment by EDTA Complexometric Titration: Implications for Soil and Agricultural Water Use

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Abstract

Water hardness, the combined concentration of dissolved calcium and magnesium ions, affects drinking-water taste, soap performance, and the formation of scale in heating equipment. In this study, total hardness was determined by direct complexometric titration with 0.01 M disodium EDTA at pH 10, using Eriochrome Black T (EBT) as the indicator. Six water types were analysed: distilled water, rain water, reverse-osmosis (RO) water, household drinking water, commercial bottled drinking water, and boiled tap water. Each 100 mL sample was buffered, indicated, and titrated to the pink-to-violet-blue endpoint, giving a direct conversion of 0.1 mL EDTA to 1 ppm as CaCO₃. Total hardness ranged from 1.2 ppm (lowest sample) to 142 ppm (highest sample). Comparing boiled and unboiled tap water gave a temporary hardness of 78 ppm (54.9% of total). All six samples were below the BIS acceptable limit of 200 mg/L. The results show that water source and treatment (distillation or RO versus mineral-bearing supplied water) have the strongest influence on hardness, and that the method is a low-cost, reliable way to screen water quality with basic school or college laboratory equipment. Because Ca²⁺ and Mg²⁺ also control irrigation-water quality, soil structure and the performance of sprayed agrochemicals, the results are converted to meq/L and interpreted for agricultural use, as a water-side companion. Hardness alone cannot establish irrigation suitability, which also requires sodium, bicarbonate and salinity data; the study therefore frames, rather than answers, the question of whether the hardness of the water used to prepare and apply fertilisers affects their performance.

1. Introduction

1.1 Background

Water hardness is the property of water caused mainly by dissolved calcium (Ca²⁺) and magnesium (Mg²⁺) ions, with minor contributions from iron, manganese, strontium and aluminium. By convention it is expressed as the equivalent concentration of calcium carbonate (CaCO₃) in mg/L, which is numerically equal to parts per million (ppm) for dilute aqueous samples [1,2].

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Hardness has practical consequences. Hard water reacts with soap to form insoluble scum, leaves deposits on fixtures, and builds scale inside kettles, boilers and pipes, which reduces heat transfer and efficiency [2]. At the same time, calcium and magnesium are nutritionally relevant, and the World Health Organization has not set a health-based guideline value for hardness, noting instead that acceptability depends on local conditions and consumer taste [2].

1.2 Temporary and permanent hardness

Hardness is traditionally divided into two types.

- **Temporary (carbonate) hardness** is due to dissolved bicarbonates of calcium and magnesium. On heating, these decompose and precipitate as carbonate scale:



- **Permanent (non-carbonate) hardness** is due to chlorides and sulfates of calcium and magnesium, which are not removed by boiling.

Total hardness is the sum of the two. Measuring total hardness before and after boiling therefore allows temporary hardness to be estimated by difference.

1.3 Aim and research questions

The aim of this study was to measure the hardness of six water types by EDTA titration and to compare them, and to interpret the results for soil and agricultural water use. The questions were:

1. How does hardness differ between natural (rain), treated (RO, distilled), packaged (commercial bottled) and supplied (drinking/tap) water?
2. How much of the hardness of tap water is removed by boiling?
3. Is a simple 100 mL titration sensitive enough to distinguish very soft waters from one another?
4. What do the hardness values, and the carbonate (temporary) fraction, imply for irrigation, soil structure, and the preparation and application of fertilisers and pesticides?

1.4 Context and research gap

In India, drinking-water quality is judged against IS 10500:2012, which sets an acceptable limit of 200 mg/L and a permissible limit of 600 mg/L for total hardness as CaCO_3 [7]. Many households replace or treat their supply with RO purifiers or bottled water, and boil water before use, but the effect of each practice on hardness is not always obvious to the user. EDTA titration has been used to characterise hardness in groundwater across Gujarat, for example in the bore wells of forty villages of Gandhinagar taluka [8], and elsewhere in South Asia, where a study of ground drinking water in Vehari, Pakistan reported total hardness between 110 and 530 mg/L [9].

Most such studies sample a single type of source. Few simple studies put natural (rain), treated (distilled, RO), packaged and supplied water, and the effect of boiling, through one identical titration procedure. This study addresses that gap at a scale that can be reproduced in a school or college laboratory.

1.5 Relevance to soil and agriculture

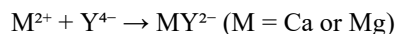
Hardness is also an agricultural variable. Calcium and magnesium are secondary plant nutrients, and Ca^{2+} in particular holds soil particles together in stable aggregates. Irrigation water that supplies Ca^{2+} and Mg^{2+} in balance with sodium helps keep soil structure open, whereas water that is very low in dissolved salts, or high in sodium relative to Ca^{2+} and Mg^{2+} , can reduce infiltration and disperse soil [10,11]. Irrigation guidelines therefore rate water using the sodium adsorption ratio, $\text{SAR} = \text{Na}^+ / \sqrt{[(\text{Ca}^{2+} + \text{Mg}^{2+})/2]}$, and the residual sodium carbonate, $\text{RSC} = (\text{CO}_3^{2-} + \text{HCO}_3^-) - (\text{Ca}^{2+} + \text{Mg}^{2+})$, with concentrations in meq/L [10,11]. The total hardness measured by EDTA titration supplies the $(\text{Ca}^{2+} + \text{Mg}^{2+})$ term of both. Hardness also matters in the irrigation line and the spray tank: calcium–magnesium carbonate scale clogs drip emitters [12], and hard-water cations can reduce the activity of some pesticides, such as glyphosate [13].

The author's earlier project, EcoGrow, compared jeevamrut, a fermented natural fertiliser made from cow dung, cow urine, jaggery, pulse flour and soil, with chemical fertiliser on experimental plots of *Colocasia esculenta*, supported by laboratory soil analysis (N, P, K and organic carbon). Water is common to both sides of such a comparison: it is the medium in which jeevamrut is prepared, the irrigation applied to the plots, and the carrier for dissolved chemical fertiliser. This study characterises that water side with a method a school laboratory can run, and Section 5.7 interprets the results for soil and farm use.

2. Theory

2.1 EDTA as a complexing agent

Ethylenediaminetetraacetic acid (EDTA) is a hexadentate ligand. Its fully deprotonated form, Y^{4-} , wraps around a metal ion and forms very stable 1:1 complexes with Ca^{2+} and Mg^{2+} :



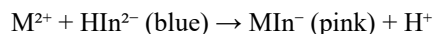
Because every mole of EDTA reacts with one mole of Ca^{2+} or Mg^{2+} regardless of the metal, the titration measures the sum of both ions directly [3,4].

2.2 Role of the pH 10 buffer

The fraction of EDTA present as Y^{4-} depends strongly on pH. At low pH most EDTA is protonated (H_2Y^{2-} , HY^{3-}) and binds metal ions weakly, which gives a drawn-out, indistinct endpoint. At pH 10 the Y^{4-} fraction is large enough for complete reaction with Ca^{2+} and Mg^{2+} , while the pH is not so high that $\text{Mg}(\text{OH})_2$ or $\text{Ca}(\text{OH})_2$ precipitates. EBT also shows its sharpest colour change near this pH. An ammonia/ammonium chloride buffer is used to hold the pH at about 10 [3,5].

2.3 The EBT indicator

EBT is itself a metal-ion indicator. Free EBT at pH 10 is blue. When Ca^{2+} or Mg^{2+} is present it forms a wine-red/pink metal–indicator complex:



During titration EDTA first binds free metal ions. Near the endpoint it pulls the metal out of the weaker M–EBT complex, releasing free blue indicator:



The observed change from pink to violet-blue therefore marks the point at which essentially all Ca^{2+} and Mg^{2+} have been complexed [3,5].

2.4 Why the conversion is 0.1 mL = 1 ppm

For a 100 mL sample titrated with 0.01 M EDTA, 1.00 mL of titrant contains

$$0.01 \text{ mol/L} \times 0.00100 \text{ L} = 1.0 \times 10^{-5} \text{ mol EDTA}$$

which reacts with $1.0 \times 10^{-5} \text{ mol}$ of $\text{Ca}^{2+}/\text{Mg}^{2+}$. Expressed as CaCO_3 (molar mass 100.09 g/mol):

$$1.0 \times 10^{-5} \text{ mol} \times 100.09 \text{ g/mol} = 1.001 \times 10^{-3} \text{ g} = 1.001 \text{ mg CaCO}_3$$

That mass is dissolved in 0.100 L of sample, so the concentration is $1.001 \text{ mg} / 0.100 \text{ L} \approx 10.0 \text{ mg/L}$. Hence **1.00 mL EDTA $\equiv$ 10 ppm**, or equivalently **0.1 mL $\equiv$ 1 ppm**, which is the factor used throughout this study.

General formula:

$$\text{Hardness (mg/L as CaCO}_3\text{)} = (\text{V_EDTA} \times \text{M_EDTA} \times 100,090) / \text{V_sample}$$

with V_EDTA and V_sample in mL and M_EDTA in mol/L.

3. Materials and Methods

3.1 Reagents and apparatus

Item	Specification
Titration	0.01 M disodium EDTA solution
Buffer	Ammonia/ammonium chloride buffer, pH $\approx$ 10
Indicator	Eriochrome Black T (1–2 drops per titration)
Glassware	50 mL burette (graduated 0.1 mL), 100 mL pipette or measuring cylinder, 250 mL conical flasks, white tile
Heating	Hot plate or burner, beaker, filter paper and funnel

Solution preparation. The 0.01 M titrant was prepared by dissolving 3.72 g of analytical-grade disodium EDTA dihydrate ($M = 372.24 \text{ g/mol}$) in distilled water and diluting to 1.00 L. The pH 10 buffer and EBT indicator were prepared following Standard Methods 2340 C [1].

3.2 Samples

Six samples were studied:

1. **Distilled water** (reference/blank)
2. **Rain water**, collected in a clean plastic container in the open, away from roofs and trees
3. **RO water**, from a domestic RO purifier
4. **Drinking water**, from the household supply
5. **Commercial bottled drinking water**
6. **Boiled tap water**, prepared from the drinking-water sample as described in 3.4

Sampling details. All samples were collected in clean polyethylene bottles rinsed three times with the sample, kept at room temperature, and analysed within 24 hours. The 100 mL portions were measured with a measuring cylinder

3.3 Titration procedure

For every sample:

1. 100 mL of sample was measured into a clean 250 mL conical flask.
2. 5 mL of pH 10 buffer solution was added and the flask swirled.
3. 1–2 drops of EBT indicator were added. Samples containing hardness ions turned wine-red/pink.
4. The solution was titrated against 0.01 M EDTA from the burette with continuous swirling, adding titrant dropwise near the endpoint.
5. The endpoint was taken as the first stable change from pink to violet-blue, judged against a white tile.
6. The burette volume was recorded to 0.05 mL. Three concordant titrations (agreeing within 0.1 mL) were recorded for each sample.

3.4 Preparation of boiled tap water

A volume of tap water (about 150 mL) was boiled for 5 minutes in a clean beaker, allowed to cool to room temperature, and filtered to remove precipitated CaCO_3 . The volume was restored to the original value with distilled water to correct for evaporation, then 100 mL was titrated as in 3.3.

3.5 Classification

Results were classified using the commonly applied scale: soft (0–60 ppm), moderately hard (61–120 ppm), hard (121–180 ppm) and very hard (>180 ppm) as CaCO_3 [2,6].

3.6 Data analysis

For each sample, the mean titre of three trials and the sample standard deviation ($n - 1$) were calculated, and hardness and its standard deviation were converted to ppm using the factor in Section 2.4. The relative standard deviation ($RSD = SD \div \text{mean} \times 100$) was used to compare precision between samples. Temporary hardness was taken as the difference between the mean hardness of the supplied water and that of the boiled water.

3.7 Safety

Safety glasses and gloves were worn, the ammonia-based buffer was handled in a well-ventilated area, and the hot plate was used with care when boiling samples. Titration waste was collected and disposed of as directed by the laboratory supervisor.

4. Results

4.1 Raw titration data

Table 1. EDTA volumes required to reach the endpoint (100 mL samples).

Sample	Trial 1 (mL)	Trial 2 (mL)	Trial 3 (mL)	Mean (mL)
Distilled water	0.10	0.10	0.15	0.12
Rain water	0.30	0.35	0.30	0.32
RO water	1.50	1.55	1.45	1.50
Drinking water	14.20	14.30	14.10	14.20
Commercial bottled water	4.10	4.20	4.00	4.10
Boiled tap water	6.40	6.30	6.50	6.40

4.2 Calculated hardness

Using $0.1 \text{ mL} \equiv 1 \text{ ppm}$, hardness in ppm = mean volume (mL) $\times 10$.

Table 2. Total hardness expressed as CaCO_3 .

Sample	Mean volume (mL)	Hardness (ppm)	Standard deviation (ppm)	Classification
Distilled water	0.12	1.2	0.3	Soft
Rain water	0.32	3.2	0.3	Soft
RO water	1.50	15.0	0.5	Soft

Sample	Mean volume (mL)	Hardness (ppm)	Standard deviation (ppm)	Classification
Drinking water	14.20	142	1.0	Hard
Commercial bottled water	4.10	41.0	1.0	Soft
Boiled tap water	6.40	64.0	1.0	Moderately hard

The relative standard deviation ranged from 0.7% (drinking water) to 24.7% (distilled water). Precision was therefore high for the harder samples, while the larger RSD values for distilled water (24.7%) and rain water (9.1%) reflect the fixed 0.05 mL reading resolution applied to titres of only about 0.1–0.3 mL (Section 5.3).

4.3 Worked calculation

The drinking-water sample needed a mean of 14.20 mL of EDTA:

$$\text{Hardness} = 14.20 \text{ mL} \times 10 \text{ ppm/mL} = \mathbf{142 \text{ ppm}}$$

Substituting into the general formula in Section 2.4 gives $(14.20 \times 0.01 \times 100,090) \div 100 = 142.1 \text{ mg/L}$, which agrees with the shortcut value of 142 ppm to within rounding.

4.4 Temporary hardness

Temporary hardness was estimated by difference:

$$\text{Temporary hardness} = \text{Total hardness (drinking water)} - \text{Permanent hardness (boiled drinking water)}$$

$$= 142 \text{ ppm} - 64 \text{ ppm} = \mathbf{78 \text{ ppm}}$$

and the fraction removed by boiling is $(\text{temporary} \div \text{total}) \times 100 = 54.9 \%$.

4.5 Graphical summary

Figure 1 summarises Table 2. Hardness is lowest in distilled and rain water, intermediate in RO and bottled water, and highest in the supplied water; boiling roughly halves the hardness of the supplied water.

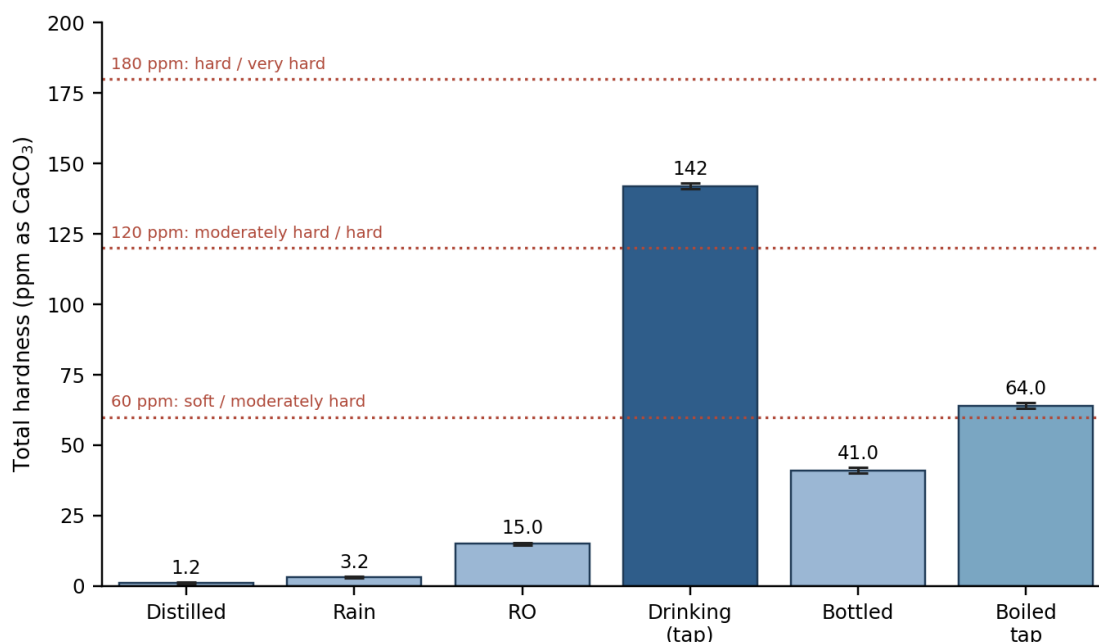


Figure 1. Total hardness of the six water samples (mean $\pm$ SD, n = 3). Dotted lines mark the classification boundaries at 60, 120 and 180 ppm as CaCO₃.

5. Discussion

5.1 Comparison across sample types

Distilled water. Distillation removes dissolved ions, so hardness should be at or near zero. A titre of 0.12 mL, close to the blank, would confirm the reagents and technique are sound. With nothing to complex, the indicator may be blue from the start, since EBT needs some Mg²⁺ to give a clear pink start colour.

Rain water. Rain forms by condensation and contains very little dissolved calcium or magnesium, but it is not perfectly pure. It dissolves atmospheric CO₂ (making it mildly acidic) and can carry dust, sea spray and industrial aerosols. The measured value of 3.2 ppm was low and only slightly above distilled water, consistent with trace dust or aerosols from the atmosphere or the collection container.

RO water. Reverse osmosis rejects most dissolved ions through a semi-permeable membrane, typically leaving low hardness. The measured 15.0 ppm is more than ten times the distilled-water value but about 89% lower than the 142 ppm of the supplied water, consistent with effective membrane rejection. The residual hardness may reflect incomplete rejection, membrane ageing, or the mineral-retention stage that many household units include.

Drinking water. Supplied and borewell water picks up Ca²⁺ and Mg²⁺ as it passes through limestone, dolomite and other mineral-bearing rock, so it normally has the highest hardness among the samples. The measured value of 142 ppm placed it in the hard category.

Commercial bottled water. Bottled water varies by brand and process: some is RO or distilled water with added minerals, others are natural mineral waters. The measured 41.0 ppm places it in the soft category and well below the supplied water, consistent with packaged water that has been treated and then re-mineralised.

Boiled tap water. Boiling lowered the hardness from 142 ppm to 64 ppm, a fall of 78 ppm (54.9%), moving the water from the hard to the moderately hard category. The remaining 64 ppm is permanent hardness.

5.2 Temporary hardness and scale

The temporary hardness found (78 ppm, or 54.9 % of total) is the portion that precipitates as scale in kettles, geysers and boilers. The CaCO_3 layer is a poor heat conductor, so scale increases energy use and shortens equipment life [2]. The remaining permanent hardness is not removed by boiling and requires ion exchange, lime–soda softening or membrane processes.

5.3 Sensitivity and reliability of the method

With 0.01 M EDTA and a 100 mL sample, each 0.1 mL of titrant is 1 ppm. A burette read to ± 0.05 mL therefore limits the reading precision to about ± 0.5 ppm per reading. This is acceptable for hard and moderately hard samples but is comparable to the total hardness of very soft samples (rain, RO, distilled), so differences of only a few ppm between those samples should be interpreted cautiously. Titrating a larger sample volume (e.g. 250 mL) or using a more dilute titrant would improve resolution.

The precision data support this. The RSD was below 1% for the supplied water but about 25% for distilled water, because a fixed ± 0.05 mL reading is a much larger fraction of a 0.1 mL titre. A second uncertainty comes from the 100 mL portion: a measuring cylinder is typically accurate to about ± 1 mL ($\pm 1\%$), which would add roughly ± 1.4 ppm to the 142 ppm result, more than the burette reading uncertainty of ± 0.5 ppm. A volumetric pipette (about ± 0.1 mL) is preferable.

5.4 Sources of error

- **Endpoint judgement.** The pink-to-violet-blue change is gradual, and different observers may stop at slightly different points. Using a white tile and a reference flask kept at the endpoint colour reduces this error.
- **Slow endpoint near equilibrium.** The Mg-EBT complex dissociates slowly, so titrant added too fast can overshoot.
- **Interfering ions.** Iron, copper, zinc and manganese can block or fade the indicator, and borewell water can contain such metals. A masking agent (for example a few drops of 1% NaCN or triethanolamine, used only under proper supervision) is normally used in standard methods [3]; this was not used here.
- **Contamination.** Tap water rinsed glassware or an unclean collection container adds hardness to soft samples.
- **Total hardness only.** The titration gives the sum of calcium and magnesium and cannot show how much of each is present. Calcium alone can be found by titrating at pH 12–13 with a calcium indicator such as murexide, where Mg(OH)_2 precipitates, and magnesium then follows by difference.
- **Aliquot volume.** Using a measuring cylinder instead of a volumetric pipette for the 100 mL sample adds about $\pm 1\%$ uncertainty (Section 5.3).

- **Indicator and buffer ageing.** EBT solution degrades within days; use a fresh solution or solid indicator mix.
- **Evaporation during boiling.** If volume was not restored, the boiled-water hardness is overestimated and temporary hardness underestimated.
- **EDTA standardisation.** If the EDTA solution was not standardised against a primary standard such as CaCO_3 , its true concentration may differ from 0.01 M and shift every result by the same percentage.

5.5 Suggestions for improvement

Standardise the EDTA against calcium carbonate, run a reagent blank, use a masking agent where metal interferences are suspected, repeat each titration until three results agree within 0.1 mL, and compare results with a conductivity or TDS meter or with a certified laboratory value for at least one sample. Extensions specific to agricultural use are given in Section 5.7.

5.6 Comparison with standards and published work

Against IS 10500:2012, which gives an acceptable limit of 200 mg/L and a permissible limit of 600 mg/L for total hardness as CaCO_3 [7], all six samples complied: the highest value, 142 ppm for the supplied water, is about 71% of the acceptable limit. The supplied water is nevertheless “hard” on the scale in Section 3.5 [2,6], which fits the scale and soap effects described in Section 1.1. The WHO sets no health-based guideline value for hardness [2], so the results are best read as an indication of acceptability and household impact rather than health risk.

The EDTA method used here is the same one used in published regional studies. Shah et al. applied EDTA titration to total, calcium and magnesium hardness of bore-well water in forty villages of Gandhinagar taluka, Gujarat [8], and Ghani et al. reported total hardness of 110–530 mg/L in groundwater from Vehari, Pakistan [9]. The supplied water measured here (142 ppm) lies within the Vehari range, although the comparison is only indicative because the sources, regions and sampling dates differ. Unlike those groundwater surveys, this study also quantifies how treatment changes hardness: RO treatment removed about 89% of the hardness of the supplied water (142 to 15 ppm), whereas boiling removed 55% and left the water in the moderately hard category.

5.7 Implications for soil and agriculture

Irrigation indices are expressed in meq/L, and 1 meq/L of Ca^{2+} or Mg^{2+} corresponds to 50 mg/L as CaCO_3 , so the hardness values in Table 2 convert directly (Table 3). The conversion gives only the $(\text{Ca}^{2+} + \text{Mg}^{2+})$ term of SAR and RSC [10,11]. Sodium and bicarbonate were not measured, so neither index can be calculated from these data.

Table 3. Hardness converted to meq/L and read against agricultural use.

Sample	Hardness (ppm as CaCO_3)	$\text{Ca}^{2+} + \text{Mg}^{2+}$ (meq/L)	Reading for agricultural use
Distilled water	1.2	0.02	Reference only; supplies essentially no Ca^{2+} or Mg^{2+}
Rain water	3.2	0.06	Soft, low-salt carrier for sprays and liquid fertilisers; supplies no $\text{Ca}^{2+}/\text{Mg}^{2+}$; very low-salt water alone can reduce infiltration [10]

Sample	Hardness (ppm as CaCO ₃)	Ca ²⁺ + Mg ²⁺ (meq/L)	Reading for agricultural use
RO water	15.0	0.30	As for rain water; the RO reject stream (not analysed) is expected to be harder than the feed
Drinking (supplied) water	142	2.84	Hard; supplies Ca ²⁺ /Mg ²⁺ but about 55% is carbonate-type, so alkalinity, sodium and scaling should be checked before irrigation or tank mixing
Commercial bottled water	41.0	0.82	Not an agricultural source; reference only
Boiled tap water	64.0	1.28	Permanent hardness only; carbonate fraction removed

Supplied water. At 142 ppm (2.84 meq/L) the supplied water carries a useful load of Ca²⁺ and Mg²⁺, which are secondary plant nutrients, and Ca²⁺ in particular helps hold soil in stable aggregates [10]. Whether it is safe to irrigate with depends on sodium and bicarbonate. The temporary hardness found in Section 4.4 (78 ppm, 1.56 meq/L, 54.9% of the total) indicates that more than half of the hardness is carbonate-type. As such water dries in soil, in drip lines or on leaves, calcium and magnesium carbonates precipitate. In soil this removes Ca²⁺ and Mg²⁺ from solution and raises the relative proportion of sodium, which is the mechanism behind the RSC index [10,11]; in micro-irrigation the same precipitation scales emitters [12]. Because temporary hardness was estimated by boiling, this is an indication rather than a measured alkalinity, and bicarbonate should be titrated directly.

Soft waters. Rain and RO water (0.06 and 0.30 meq/L) supply almost no Ca²⁺ or Mg²⁺. That makes them suitable carriers for foliar sprays and liquid fertilisers, where cations from the water can interfere, but not a source of calcium or magnesium for the crop, and very low-salt water used as the only irrigation source can reduce infiltration into soil [10]. RO units also discharge a reject stream that concentrates the rejected salts and is sometimes reused on gardens. It was not analysed here but would be expected to be harder than the 142 ppm feed.

Agrochemical spray water. Ca²⁺ and Mg²⁺ in a spray tank can bind weak-acid active ingredients. For glyphosate, calcium reduced foliar absorption and ammonium sulfate restored it [13]. A hard supply such as the one tested here is therefore the kind of water for which this antagonism is a recognised concern, whereas rain and RO water are not.

Fertilisers and jeevamrut. Published reports differ on how jeevamrut works: combined with vermicompost it raised available N, P and K and microbial counts in pomegranate soil [14], whereas a multi-site rice study found it to be a poor plant-available macronutrient reservoir whose contribution may lie in the plant-growth-promoting bacteria it carries [15]. Comparisons of this kind, including EcoGrow, would be easier to interpret if the hardness of the water used to prepare jeevamrut, to irrigate the plots and to dissolve chemical fertiliser were reported alongside them. Whether the Ca²⁺ and Mg²⁺ content of that water changes the fermentation of jeevamrut (its pH, microbial load or nutrient forms), or the behaviour of chemical fertilisers such as phosphates, which can precipitate with Ca²⁺, was not tested here and is the main open question this work points to.

Scope of these inferences. All six samples were domestic, packaged or atmospheric waters. None was a farm borewell, canal or stored irrigation water, no soil was analysed and no plant response was measured, so the agricultural reading above is an interpretation of hardness values against published criteria, not a test of crop or soil effects. To make the link quantitative, Na⁺ (by flame photometry), EC, pH and bicarbonate alkalinity should be measured on farm water so that SAR and RSC can be calculated; exchangeable Ca²⁺ and Mg²⁺ should be measured in soil irrigated with

waters of differing hardness; and jeevamrut prepared with waters of known hardness should be compared with a chemical-fertiliser control on the same crop.

6. Conclusion

EDTA complexometric titration at pH 10 with Eriochrome Black T is a simple, inexpensive and fairly precise way of measuring water hardness without specialised instrumentation. Across the six waters tested, total hardness ranged from 1.2 to 142 ppm as CaCO_3 , with drinking water the hardest and distilled water the softest. Boiling the drinking water reduced hardness by 78 ppm, which is the temporary hardness caused by bicarbonates. The expectation that rain, distilled and RO water would be softest and supplied water hardest was supported. All six samples were below the BIS acceptable limit of 200 mg/L, RO treatment removed about 89% of the hardness of the supplied water, and boiling removed about 55%. Interpreted for agriculture (Section 5.7), the supplied water carries 2.84 meq/L of $\text{Ca}^{2+} + \text{Mg}^{2+}$, more than half of it carbonate-type, while rain and RO water carry almost none. These values are a necessary input to, but not a substitute for, irrigation indices such as SAR and RSC, which also need sodium and bicarbonate data. The question this study leaves open is whether the hardness of the water used to ferment and apply liquid formulations such as jeevamrut, or to spray agrochemicals, changes how those inputs perform in soil. Limitations in endpoint detection, titrant standardisation and low-hardness resolution mean the results are best treated as reliable screening values, and future work could include a wider range of sources (including farm borewell and canal water), seasonal variation, measurement of Na^+ , EC, pH and bicarbonate so that SAR and RSC can be calculated, soil measurements under irrigation of differing hardness, and comparison with instrumental methods such as ICP-OES or atomic absorption.

Data availability

The raw titration readings for all trials are given in Appendix A.

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Appendix A. Data Record Sheet

Sample	Initial burette reading (mL)	Final reading (mL)	Titre (mL)	Notes (colour, speed of endpoint)
Distilled water	0.00	0.10	0.10	Very faint pink; changes within first drops
Distilled water	0.00	0.10	0.10	Very faint pink; changes within first drops
Distilled water	0.00	0.15	0.15	Very faint pink; changes within first drops

Sample	Initial burette reading (mL)	Final reading (mL)	Titre (mL)	Notes (colour, speed of endpoint)
Rain water	0.00	0.30	0.30	Faint pink; change within a few drops
Rain water	0.00	0.35	0.35	Faint pink; change within a few drops
Rain water	0.00	0.30	0.30	Faint pink; change within a few drops
RO water	0.00	1.50	1.50	Light pink; clear endpoint
RO water	0.00	1.55	1.55	Light pink; clear endpoint
RO water	0.00	1.45	1.45	Light pink; clear endpoint
Drinking water	0.00	14.20	14.20	Wine-red; slow approach, clear violet-blue
Drinking water	0.00	14.30	14.30	Wine-red; slow approach, clear violet-blue
Drinking water	0.00	14.10	14.10	Wine-red; slow approach, clear violet-blue
Commercial bottled water	0.00	4.10	4.10	Pink; clear endpoint
Commercial bottled water	0.00	4.20	4.20	Pink; clear endpoint
Commercial bottled water	0.00	4.00	4.00	Pink; clear endpoint
Boiled tap water	0.00	6.40	6.40	Pink; clear endpoint (after filtering)
Boiled tap water	0.00	6.30	6.30	Pink; clear endpoint (after filtering)
Boiled tap water	0.00	6.50	6.50	Pink; clear endpoint (after filtering)

Appendix B. Calculation Summary

Quantity	Formula
Moles EDTA used	$M \times V \text{ (L)}$
Hardness (mg/L as CaCO_3)	$(V_{\text{EDTA}} \times M_{\text{EDTA}} \times 100,090) / V_{\text{sample}} \text{ (mL)}$
Shortcut for this method	Hardness (ppm) = titre (mL) $\times$ 10
Temporary hardness	Total hardness – hardness after boiling
% removed by boiling	$(\text{Temporary} \div \text{Total}) \times 100$