# EVEN IF YOU DEAL WITH WATER OF VARYING QUALITY, THERE ARE WAYS TO ENSURE PERFECT COFFEE EVERY TIME. LEARN HOW HERE.

How different water filter technologies affect the flavour of coffee and espresso

A BRITA WHITE PAPER

BRITA

# 1. Abstract

The chemical composition of the water used to make coffee is a major factor that needs to be taken into consideration for achieving the desired coffee flavour profile. The Specialty Coffee Association (SCA) makes quite specific recommendations in its *Water Quality Handbook*. [1] As water quality can vary considerably from place to place, it makes sense to choose the water treatment technology that is most suitable for the water used. In the following, the principal characteristics of the main ones – activated carbon filtration, decarbonisation, softening, total demineralisation, reverse osmosis and mineralisation – are described and distinguished while focusing on the sensory aspects of how they influence the flavour of coffee and espresso.

# 2. Introduction

There are a wide variety of coffee bean grades, roast levels, blends and methods of preparation: a veritable smorgasbord for coffee fans who love variety and enjoy experimenting. But for coffee roasters offering a portfolio of brands with different flavours, coffee shop chains and everyone else who has 'found' their favourite coffee and sworn loyalty to it, a consistent flavour with recognition value is very important.

Besides coffee beans and how coffee is prepared, the water has a crucial impact on the flavour of coffee.[1] Using water with an unfavourable chemical composition can cancel out the time, money and effort that have gone into defining and achieving a particular flavour profile, resulting in a sensory experience that falls short of expectations. It's therefore important to understand in detail not only how different filtration technologies work in technical terms but also how they affect coffee's flavour. This is helpful for taking steps to either amplify the desired sensory effects or reduce or eliminate undesirable ones.

# 3. Executive summary

- In professional coffee preparation, the water can be filtered for either or both of two purposes: to prevent equipment failures and to enhance sensory quality. The substances contained in the locally available water will determine the choice of water filtration technology for protecting the equipment, while it can also be influenced by sensory preferences if these are important.
- In this connection, coffee associations such as the SCA make specific recommendations regarding the ideal composition of coffee water. The overall sensory experience of coffee that is referred to as 'flavour' is composed of three components: aroma (smell), taste and body (touch; an aspect of mouthfeel).



[1] The statements in this white paper that refer to 'coffee' can generally also be applied to espresso.

- The principal filtration technologies and their effects on the flavour of coffee:
    - Filtration with activated carbon is always recommended, regardless of the composition of the initial water, as it reduces substances in it that could otherwise alter the expected aroma profile in undesirable ways.
    - Decarbonisation, total demineralisation, reverse osmosis and mineralisation all share the ability to improve different initial waters so as to give the coffee a balanced coffee flavour. Both decarbonisation and mineralisation support optimal development of the coffee's sourness, the first by enhancing it and the second by inhibiting it.
    - Softening amplifies the roasted aromas and increases the coffee's bitterness, an effect that is typically associated with Italian coffee.

- The described effects only apply to black coffee and espresso and not to coffee-based mixed drinks like cappuccino.

- Even when different water treatment products use the same technology (e.g., decarbonisation), the resulting overall sensory experience can diverge.

## 4. Why does it make sense to filter the water for making coffee?

Open a textbook and you'll find a definition of water that goes something like this: 'a chemical compound with a molecule comprising two hydrogen atoms and one oxygen atom ($H_2O$).' However, chemically pure water doesn't occur in nature. Water is known as a universal solvent because it is able to dissolve a wide range of other substances. When water from precipitation percolates through the ground, it picks up other atoms and molecules along the way. So the water we encounter in our everyday lives (in oceans, lakes, rivers, groundwater and tap water etc.) inevitably contains a blend of minerals and chemicals, and its exact composition – and therefore its properties – also varies from place to place. Other substances dissolved in the water can cause technical problems in coffee machines (for example, by leaving scale deposits) and detract from or alter the flavour of coffee brewed with water containing them. To achieve a flawless cup of coffee with an optimal, harmonious flavour, it's therefore important to avoid certain substances such as chlorine and organic molecules and adjust its mineral content to a 'good' level. The specifications of coffee associations indicate the acceptable concentrations of different minerals. [1]

Marcel Schauss, 'coffeeologist' and a member of BRITA's field service for professional filters in Germany, has experienced first-hand the evolution in recent years:

> *'I have observed that, apart from protecting equipment, the flavour of coffee also increasingly matters to more and more groups of customers. This means that not only do I have to be intimately acquainted with how different filter technologies and products work in technical terms, but I must also know how they impact the flavour of coffee.'*

## Excursion: Do all filters based on the same technology yield the same results?

Marcel Schauss, 'coffeeologist' and a member of BRITA's field service for professional filters in Germany, explains:

> *'When talking with customers I'm often asked why a competitor's filter gives coffee a different flavour even though it uses the same technology. This often causes confusion. But the fact is that a filter is more than just its technology. The quality of the filtrate can also be influenced by the device's settings and size. Take decarbonisation, for example: the composition of the water can vary depending on the amount of ion exchanger in the filter cartridge, the filtration rate, the type of buffering agent used and the proportion of unfiltered water added via a bypass. Conversely, two different filter technologies can yield a comparable water composition and therefore also comparable sensory properties. It's always necessary to find out whether the filter technology per se is meant or they're talking about a particular make of filter for a special application. A filter really is more than its technology."*

A well-trained customer service representative can generally be counted on to give advice on matching flavour preferences, which are often culturally defined.

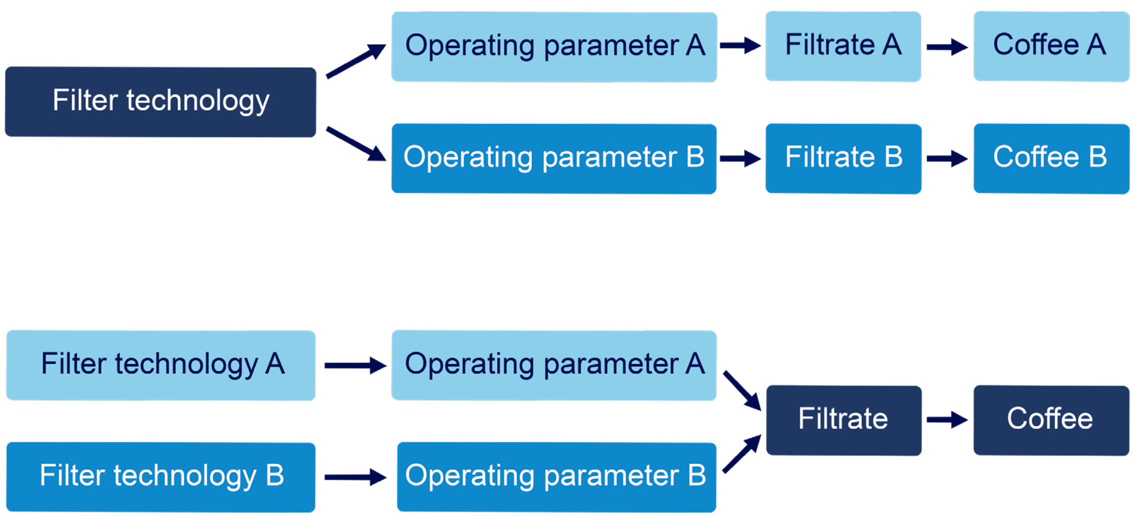


*Figure 1: Interrelationships amongst the filter technology, the filter's operating parameters, the composition of the filtrate and the resulting coffee flavour.*

# 5. Aroma, taste, body and flavour: what's the difference?

We humans use five senses to perceive food and drink: sight, hearing, smell, touch and taste. In the case of coffee, three are particularly important: smell, taste and touch:

- We use the olfactory bulb, a brain structure at the back of our nose, to smell substances that give off odours (so-called odour-active substances). These define the aroma of coffee. Aromas can also be perceived retronasally: when we take a sip of coffee, the aromas migrate from the oral cavity into the nose and reach the olfactory bulb via this route.

- We use our tongue and its receptors to detect the five basic tastes: sweet, sour, salty, bitter and savoriness (often called by its Japanese name, umami). Together they define the taste of a food or beverage. We're unable to taste anything that we perceive apart from them. For example, if coffee has a chocolaty aroma we don't taste it but only smell it (an example of retronasal perception).

- The surfaces of our mouth are covered with tactile nerve endings which let us feel the consistency of a food or beverage, which is called mouthfeel. In the case of coffee, body is one of several tactile sensations. It is usually defined as the perceived viscosity, weight or fullness of the coffee as we swirl it around in our mouth. [2]

These three sensory inputs combine to create the overall sensory impression of a coffee's flavour. In a narrow sense, flavour is thus a composite of aroma, taste and mouthfeel. More broadly, it is also defined by what we see, hear and feel with our hands. [3]

If you ask ten coffee lovers what 'good' coffee is, you'll receive ten different answers. Every coffee drinker has their own definition of 'good' coffee, and it can vary greatly depending on family or regional customs. Some people, for example, prefer coffee with a distinctly sour note, while others favour coffee with a bitter taste. Nevertheless, coffee experts agree that, for the majority of coffee drinkers, a harmonious balance of flavours is important for a 'good' coffee. All of the relevant sensory dimensions – like aroma, taste and mouthfeel – should be in an equilibrium in relation to one another. No single attribute – such as sourness, bitterness, fruitiness or roasted aromas – should dominate, and the coffee's body should be neither too thin or watery nor too thick or heavy. [2]

# Overview of the most popular filtration technologies and their effects on water and coffee

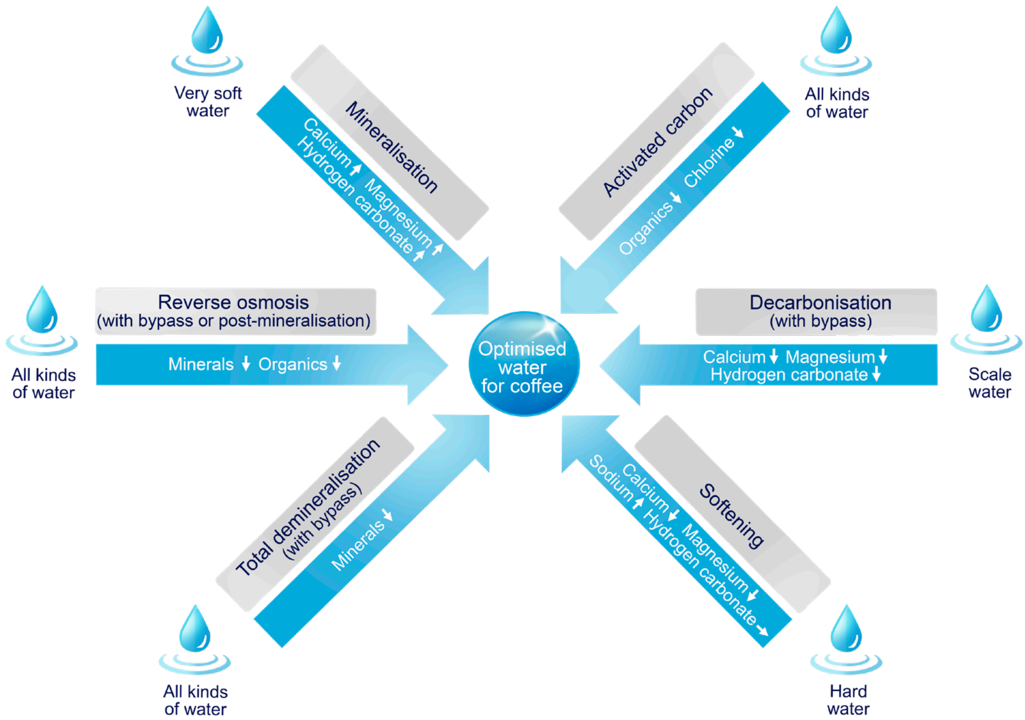


*Figure 2: How different water treatment technologies can affect the chemical composition of water.*

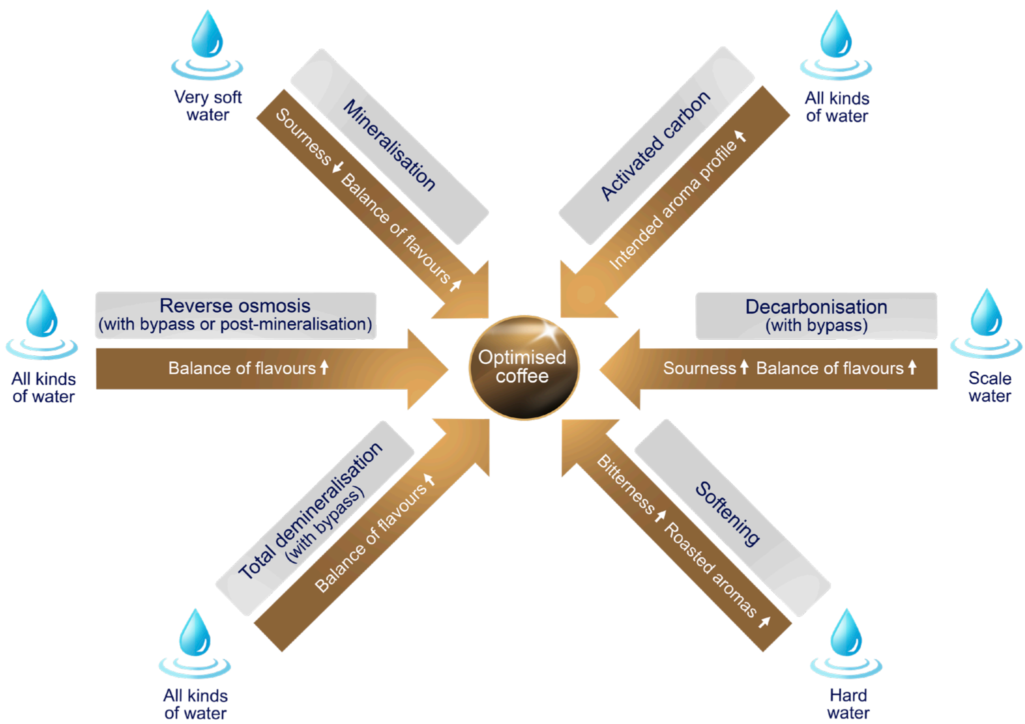


*Figure 3: The sensory impact of different water treatment technologies on coffee depending on the composition of the initial water.*

## 6. The various filter technologies in detail

The possible ways in which filter technologies can affect the sensory experience of coffee are described in greater detail below. Please note:

- The presented sensory effects are limited to black coffee and espresso and cannot be applied one-to-one to coffee-based mixed beverages such as cappuccino. This is because ingredients such as milk and sugar can alter the effects and are also added in differing amounts depending on each individual's preferences.

- The described sensory effects are virtually universal. In other words, they are experienced in this way by the vast majority of people. Due to the subjective nature of sensory perception, however, they can occasionally be experienced differently.

- Only those effects of the water are described in the following that have been scientifically confirmed and are largely independent of other influences. However, this does not exclude the possibility that other, specific influences not described here may also play a role.

- The flavour of coffee depends not only on the chemical composition of the water, but also on the coffee beans, how it is prepared, and subjective perceptions.

## 6.1 Activated carbon

Activated carbon is porous, fine-grained carbon. It is obtained by charring a natural carbonaceous material such as wood, peat, anthracite or coconut shells and then 'activating' it in a thermal process. This second step causes it to develop a large number of pores, thus greatly increasing its internal surface area and enabling the material to attract and hold large amounts of other substances. The internal surface area can comprise more than 1000 $m^2$, the size of four tennis courts, per gram. BRITA uses foodsafe activated carbon made from coconut shells.

Activated carbon is able to significantly reduce the organic substances in water that have an unpleasant odour. These include, for example, metabolic waste products from the bacterial decomposition of plant residues such as foliage. An example is geosmin, which can impart a stale earthy smell to groundwater and consequently also to drinking water. Depending on its concentration, this substance can also induce an atypical 'off' flavour in coffee that is perceived as 'wrong'. [4]

Activated carbon is also used as a catalyst for reducing chlorine; municipal waterworks often add it to tap water to disinfect it and prevent recontamination. Chlorine has a distinctive odour and can, in sufficiently high concentrations, also be perceived in coffee. But even when the chlorine content is quite low and therefore not noticeable as such, reducing it is a very important prerequisite for ensuring good-quality coffee. The reason is that chlorine is highly reactive and can combine with organic substances in the coffee, thus altering their structure and sensory properties. [5]

Due to the chemical and sensory changes that chlorine itself undergoes when reacting with coffee constituents, the resulting undesirable changes in the aroma profile aren't attributed to the chlorine, despite the fact that it has caused them. It is therefore always advisable to filter the water – including so-called 'soft' waters – with activated carbon.


*Figure 4: Activated carbon can reduce substances in the water that could otherwise detract from the desired and expected aroma profile of the coffee.*

## 6.2 Decarbonisation

Decarbonisation, also known as partial demineralisation, is a term applied to all water treatment methods that reduce carbonate hardness.

**Good to know** | The amount of calcium ($Ca^{2+}$) and magnesium ($Mg^{2+}$) in water determines its **total hardness**. Both are cations, meaning that they are positively charged. The share of calcium and magnesium ions associated with hydrogen carbonate ($HCO_3^-$), which is a negatively charged ion (= anion), defines its **carbonate hardness** (also called temporary hardness). The proportion of calcium and magnesium ions associated with sulphate, nitrate or chloride (all of which are anions) defines water's **permanent hardness**. The sum of the carbonate hardness and the permanent hardness is its total hardness.

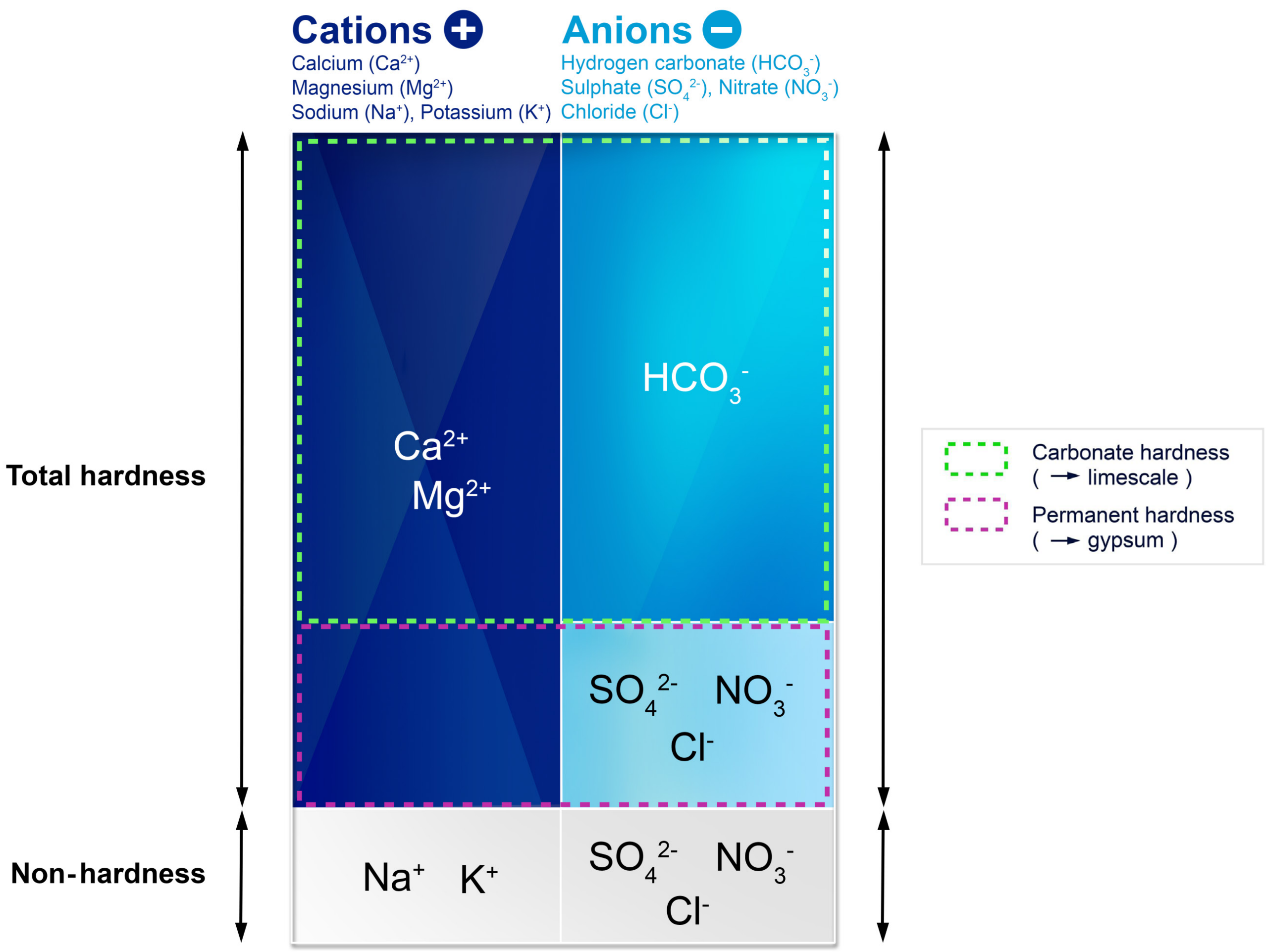


*Figure 5: The most commonly occuring mineral composition of European tap waters.*

The most widely used decarbonisation method uses a cation exchanger that replaces bound hydrogen ions ($H^+$) with calcium ($Ca^{2+}$) and magnesium ($Mg^{2+}$) cations present in the water.

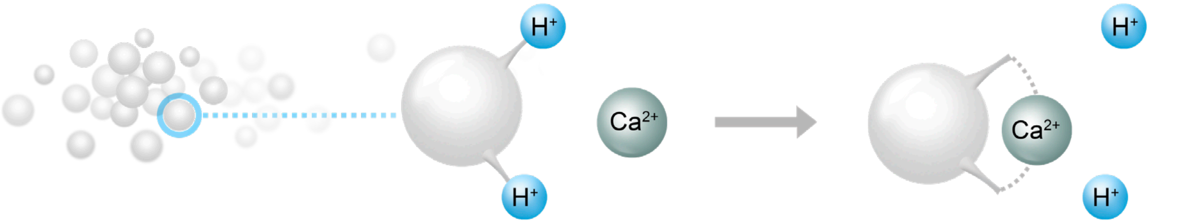


*Figure 6a: A cation exchanger with two bound hydrogen ions ($H^+$) swaps them for a calcium ion ($Ca^{2+}$).*

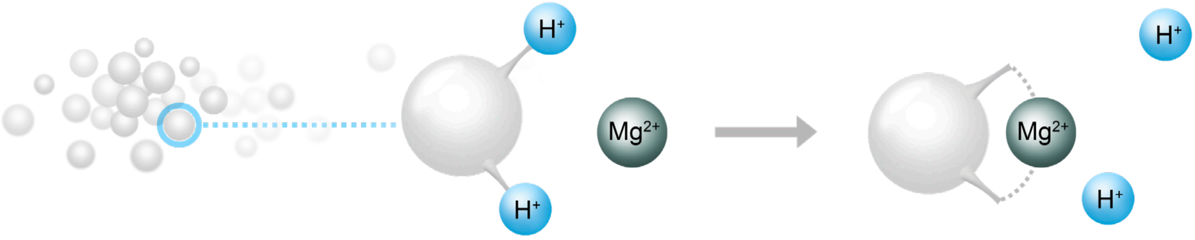


*Figure 6b: A cation exchanger with two bound hydrogen ions ($H^+$) swaps them for a magnesium ion ($Mg^{2+}$).*

Hydrogen ions that have been emitted into the water now react with the still-present hydrogen carbonate ($HCO_3^-$) to form carbonic acid ($H_2CO_3$), which in turn decays into water ($H_2O$) and carbon dioxide ($CO_2$) when heated (for example in a brewing unit). So with each successive reaction, the amount of hydrogen carbonate in the water is reduced further. [6]

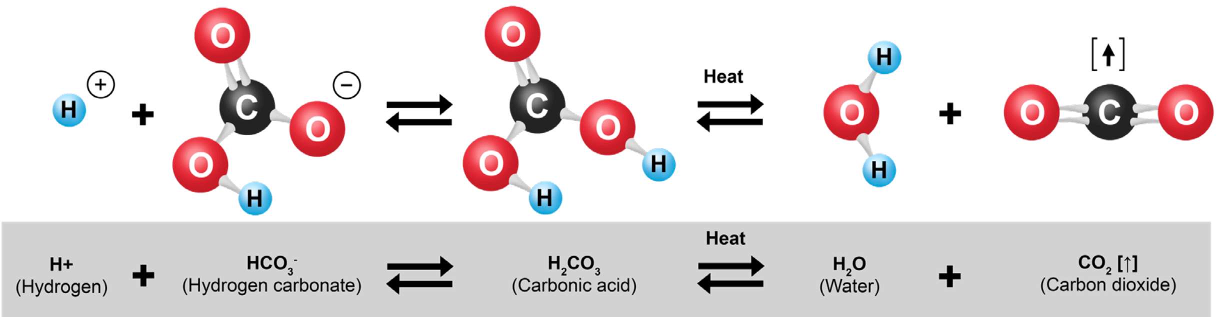


*Figure 7: Hydrogen ions ($H^+$) react with hydrogen carbonate ($HCO_3^-$) to form carbonic acid ($H_2CO_3$), which decays into water ($H_2O$) and carbon dioxide ($CO_2$) when heated.*

How does this affect coffee's sensory attributes? Acids, including those in coffee, are by definition substances that possess and readily emit hydrogen ions. If the water were **not** filtered or decarbonised, the hydrogen carbonate would react with the hydrogen ions of the acids present in the coffee. The remaining negatively charged part of the (coffee) acid left after shedding the hydrogen ions can lose its sour taste in the process. The more hydrogen carbonate is available to react with the hydrogen ions of the coffee acids, the more the coffee loses its sourness.

Conversely, if **less** hydrogen carbonate is present as a result of the **preceding** reaction with the hydrogen ions of the cation exchanger, it also reacts less with the coffee acids, which are therefore retained. [1] [6]


*Figure 8: Decarbonisation reduces the amounts of calcium ($Ca^{2+}$), magnesium ($Mg^{2+}$) and ultimately also hydrogen carbonate ($HCO_3^-$) present in the water. This can result in increased perception of the acids and improve the flavour balance of the coffee.*

Can the proportion of hydrogen carbonate affect more than sourness in a cup of coffee? This is quite possible; a perfect cup of coffee has a well-balanced profile of multiple sensory factors such as sourness, bitterness, various aromas and body. Altering any one of these attributes can affect how the others are perceived.

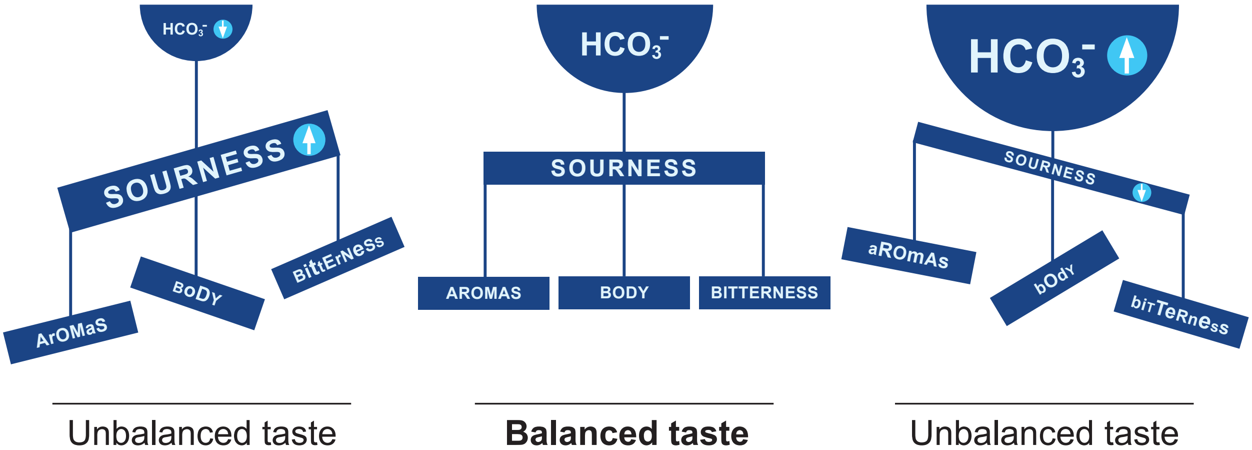


*Figure 9: **Balanced taste**: The 'right' amount of hydrogen carbonate ($HCO_3^-$) results in a coffee with a desirable balance of sourness, aroma, body and bitterness. To achieve this, coffee associations recommend brewing with water that has a carbonate hardness of 2-6 °dH. Although this parameter plays an important role in achieving great-tasting coffee, it isn't the only factor. **Unbalanced taste:** Too little or too much hydrogen carbonate can increase and decrease, respectively, the coffee's sourness, which can also impact other flavour parameters in unpredictable ways.*

**Good to know** | Hydrogen carbonate ($HCO_3^-$) directly influences sourness and is therefore the most important mineral for a balanced coffee flavour. Reducing it to the range suggested by coffee associations such as the SCA also generally keeps the amounts of calcium and magnesium ions in the right range. Attention should therefore focus on adjusting the hydrogen carbonate. Although a certain amount of calcium and/or magnesium ions is needed in order to bring out complex coffee aromas, at these concentrations it makes no difference in sensory terms whether calcium or magnesium ions are involved. [6]

## 6.3 Softening

Softening refers to all water treatment processes for reducing total hardness (the sum of carbonate hardness and permanent hardness).

Softening is accomplished with a cation exchanger to which sodium ions ($Na^+$) are bound. Unlike cation exchangers used for decarbonisation, the one used for softening is able to exchange not only the calcium and magnesium ions associated with hydrogen carbonate in the water (= carbonate hardness), but also the calcium and magnesium ions associated with the sulphate, nitrate and chloride anions (= permanent hardness). After being filtered, the water is therefore free of calcium and magnesium ions.

Unlike the cation exchanger used for decarbonisation, which emits hydrogen ions into the water in exchange for calcium and magnesium ions, a cation exchanger used for softening releases sodium ions.

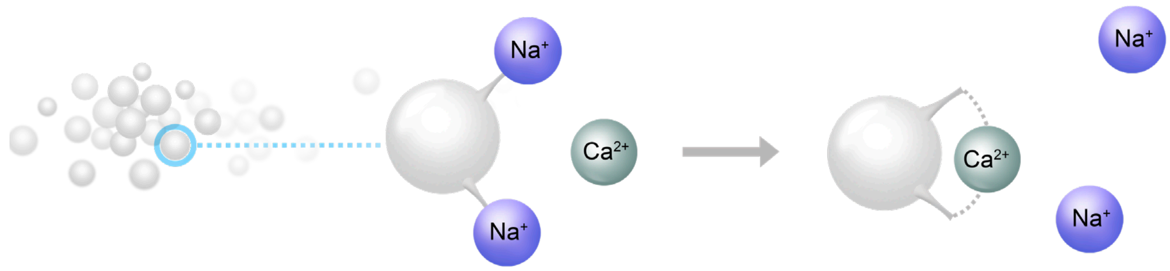


*Figure 10a: A cation exchanger with two bound sodium ions ($Na^+$) exchanges these for a calcium ion ($Ca^{2+}$).*

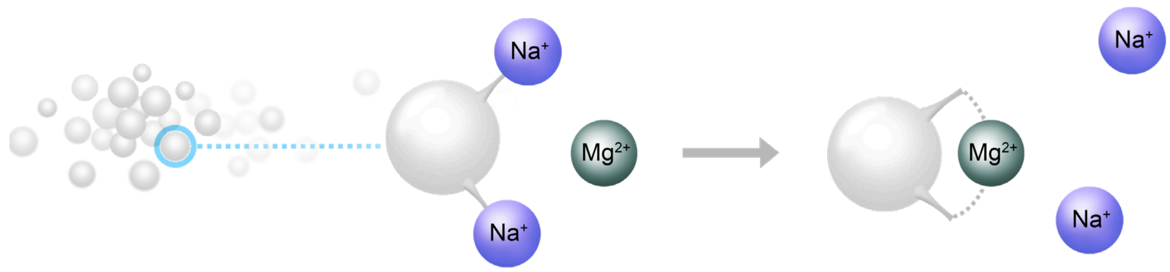


*Figure 10b: A cation exchanger with two bound sodium ions ($Na^+$) exchanges these for a magnesium ion ($Mg^{2+}$).*

The hydrogen carbonate in the water reacts with the sodium ions that have been exchanged for calcium and magnesium ions to form sodium hydrogencarbonate ($NaHCO_3$). When the filtrate is heated (for example, in a brewing unit), it splits into sodium hydroxide (NaOH), which is also known as caustic soda, and carbon dioxide ($CO_2$).

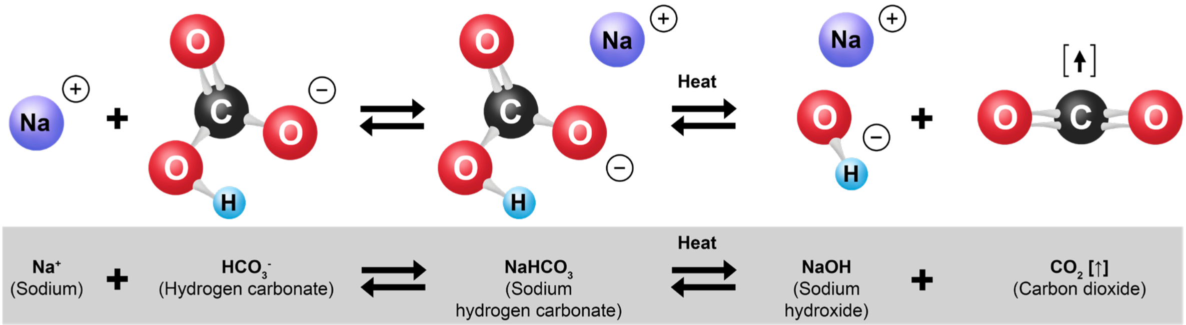


*Figure 11: Sodium ions ($Na^+$) react with hydrogen carbonate ($HCO_3^-$) to form sodium hydrogencarbonate ($NaHCO_3$), which decays into caustic soda (NaOH) and carbon dioxide ($CO_2$) when heated.*

The newly created sodium hydroxide markedly increases the pH of the wet coffee grinds, causing them to swell and become slightly compressed as a result. The hot (brewing) water therefore takes longer to flow through them, which prolongs the extraction time, removes more constituents that tend to resist dissolving and therefore increases overall extraction. The water still contains quite a bit of hydrogen carbonate, which buffers the coffee acids. This can enhance both the roasted aromas and the bitterness of the coffee. [7] [8] [9]

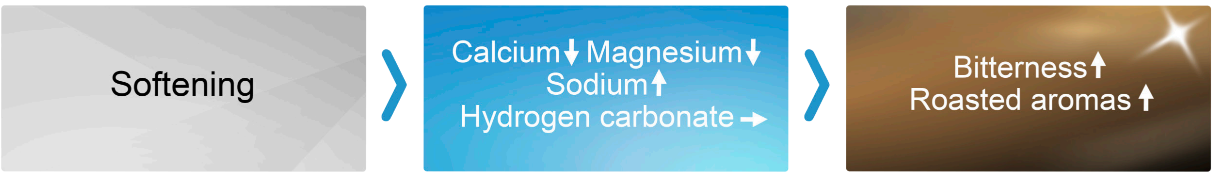


*Figure 12: Softening reduces the calcium ($Ca^{2+}$) and magnesium ions ($Mg^{2+}$) in the water and increases the sodium ions ($Na^+$) without affecting the amount of hydrogen carbonate ($HCO_3^-$) present.*

The more perceptible roasted aromas and increased bitterness result in a coffee flavour that is often referred to as ‘typically Italian’. Those who don’t enjoy this flavour profile can additionally decarbonise the filtrate. This substitutes hydrogen ions for part of the sodium ions in the water. Fewer sodium ions and hydrogen carbonate are then available, which can reduce the roasted aromas and bitterness allow the sourness to develop better.

## 6.4 Total demineralisation

Total demineralisation is a technology that involves the combined use of both cation and anion exchangers. As a result, it almost completely eliminates the cations calcium, magnesium, sodium and potassium and the anions hydrogen carbonate, sulphate, chloride and nitrate. Reducing these minerals in the water can also mitigate any adverse effects on the coffee's balance of flavours. In sensory terms, however, such chemically pure water isn't ideal. It can result in coffee with excessive sourness and weak aromas. [8] To let the aromas fully unfold while reducing the coffee acids somewhat, a certain amount of minerals must be present. [1] [6] [7] [8] This is commonly ensured by mixing the filtrate with a small quantity of (unfiltered) water from the same source via a bypass. This comes at a price, however, the added unfiltered water can also contain other, undesirable components like chloride or sulphate. Whether or not a bypass solution will work as intended in a given case depends on the types and concentrations of these unsavory substances.


*Figure 13: Total demineralisation reduces the amount of minerals in the water. This typically also improves the balance of flavours in the coffee.*

## 6.5 Reverse osmosis

In reverse osmosis, water is pressed through a membrane. The membrane's pores are so small that only water molecules, which are very tiny, can pass through them. The minerals and organics dissolved in it are all too large to wiggle through. The filtrate therefore consists almost exclusively of pure water ($H_2O$).

This somewhat more complex technology can always be deployed if other, simpler methods fail to achieve the desired effect or there is no other way to resolve a water-related sensory problem. Its advantage is that, regardless of the original water, almost all other molecules are removed leaving only chemically pure water.

The drawback is that, like total demineralisation, it yields water that isn't optimal for preparing coffee. Here too, it's a good idea to add a small amount of unfiltered water to the filtrate via a bypass. A more elegant alternative is to additionally install a post-mineralisation filter in order to make sure that only acceptable amounts of the desirable calcium and/or magnesium ions and hydrogen carbonate enter the filtrate.


*Figure 14: Reverse osmosis eliminates almost all minerals and organics from the water. This reduces the extent to which these substances detract from a balanced coffee flavour.*

## 6.6 Mineralisation

When coffee is made with water that is almost completely free of minerals, coffee acids can dominate its flavour. [6] [7] [8] This can be offset by intentionally adding a small amount of calcium and/or magnesium ions and hydrogen carbonate to enhance the balance of flavours while slightly reducing the sourness. In solutions that use reverse osmosis, mineralisation is therefore an alternative to a bypass and even superior to it in purely sensory terms, as it only channels the desired minerals into the filtrate.

Many mineralising filters use grains of stone containing calcium, magnesium and carbonate. When these minerals come into contact with slightly acidic water, they dissolve into it. It therefore makes good sense to insert a further, pH-reducing filter (such as a decarbonisation filter) ahead of the mineralisation filter to ensure that a sufficient quantity of the minerals is dissolved.


*Figure 15: Water is mineralised by intentionally adding calcium ($Ca^{2+}$) and magnesium ions ($Mg^{2+}$) and hydrogen carbonate ($HCO_3^-$) to it. This can enable the extraction of more aromas from the coffee,*

## 7. Conclusion

Suitable filter equipment can be used to purposefully adjust the chemical composition of the water and optimise the flavour of coffee as a result. Today a variety of filtration technologies are available for accomplishing this. A well-trained customer service representative can generally be counted on to give advice on matching flavour preferences.

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