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# Existing Scale Deposits Removal by Magnetic Water Treatment: Theoretical Study and Experiment

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## Abstract

Scales are hard deposit, which stick very firmly to the inner surfaces of the pipes and are very difficult to remove. This document studies the effect of magnetic water treatment on the scaling power of hard waters and shows how permanent magnets help to remove existing scale deposits in water. We demonstrate how a strong applied magnetic field increases the aragonite/calcite ratio in the deposit and thus inhibit scaling potentiality of treated water. Therefore, magnetic water treatment accelerates crystallization of mineral scales preventing them from adhering to the pipes.

**Keywords:** Magnetic water treatment; Permanent magnets; Aragonite; Scale deposits

## Introduction

Mineral salts play an extremely important role in the metabolism of all organic matter, which forms the basis of all biological processes. From the ground, the dissolved minerals are later transported by water in our pipes and installations. Metallic ducts offer possibilities of higher chemical bonds than water, and attract these minerals, which are recrystallized in the form of tartar [1]. When soluble calcium bicarbonate, $Ca(HCO_3)_2$ , turns into $CaCO_3$ tartar, the result is doubly harmful, as water loses its mineralization and deposits damage the installations causing an extra energy consumption (up to 25%) and a high maintenance cost [2]. The below chemical equation describes the decomposition of calcium bica rbonate into calcium carbonate:

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

Scale composed mainly from calcium carbonate is soft and is the main cause of scale formation. In order to remove scaling, industrials often resort to chemical treatment which attacks scales deposit and clean pipes. Unfortunately, this method has a number of drawbacks: it is costly in money and time and presents health hazards. As an alternative, magnetic treatment offers an economical, more efficient and less dangerous solution: it modifies the physical properties without affecting the chemical structure of water.

In this work, we investigate the effect of permanent magnet on the characteristics of water and show how a strong magnetic field helps to remove lime scale deposits by increasing the aragonite: calcite ratio in the mixture from a 20:80 before the magnetic conditioning of water to an optimal ratio of 80:20 afterwards [3]. (Figure 1 indicates the difference between the two calcium carbonate polymorphs: calcite as a hard scale and aragonite as a soft scale).

Thus, the magnetic water treatment accelerates the crystallization of mineral deposits preventing them from adhering to the piping [4].

## Water Under Magnetic Field

Water is a colorless, odorless, tasteless liquid. It is a polar liquid, which means that it has a dipole moment defined as follows: In each molecule, the atoms with their electrons and nuclei are arranged so that one part of the molecule has a positive electrical charge while the other part is negatively charged. Such a molecule, therefore, becomes a small dipole. The change of the magnetic field causes the molecules to rotate, in one direction or the other, depending on the field load: taking a higher positive or negative potential. In the presence of a magnetic field, these molecules will react as a function of the net charge of the external force.

The magnetic device brings a single positive (+) pole to the pipe [5]. This positive charge physically configures the fluid so that the negative poles of the molecules are attracted by the magnetic source. Therefore, a polarized and linear structural reorganization is created. The activated and amplified molecules (magnetized) react like small magnets Because of Lorentz force which generates magneto-hydrodynamics effects [6] (Figure 2 explains this phenomenon).

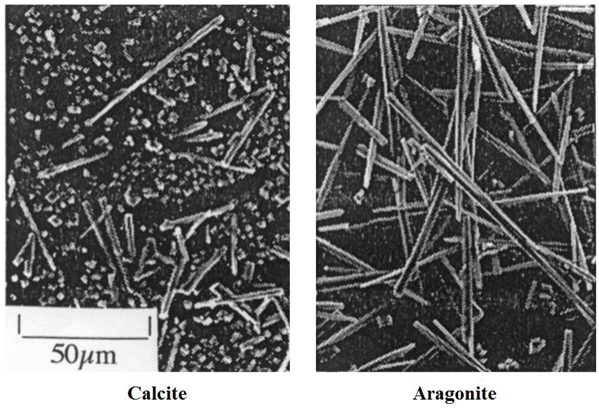


**Figure 1:** Calcite vs Aragonite

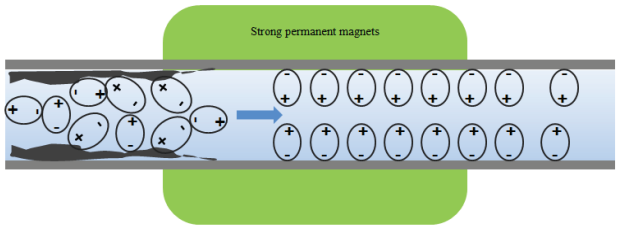


**Figure 2:** Applied magnetic field effect on hard waters

For the $H_2O$ molecule, the bonds of the hydrogen and oxygen atoms are changed from a triangular structure to a linear structure. In a "linear" magnetized state, the more charged hydrogens ($H^+$) tend to attract the oxygen more negatively charged. As a result, the ionic field changes the net charge of water from negative (-) to positive (+).

Thus, by treating a polar fluid with a correctly focused and sufficiently powerful magnetic field, we can control the orientation effect of atoms that affect molecular change. More precisely, the magnetic field increases the surface energy of small particles, and keeps them small and highly soluble. Their tendency to form a calcareous precipitate becomes considerably reduced.

By treating the water with the appropriate magnetic field, crystallizations of calcium carbonate and hard relative minerals (limestone) will increase their water content. When tartar forms, it is in less hydrated form. In the case of calcium carbonate, the magnetic effect makes the crystals completely hydrated (saturated water) and change them into the aragonite form. The magnetic treatment increases the water content of this branched crystalline structure, thereby weakening it.

Finally, the limestone dissolves into aragonite formed of softer calcium carbonate, whereas the old limestone was hard and consequently hardly attached to the wall. This increased flocculation, ie a larger particle size, remains suspended in the water and therefore, depending on the equipment concerned (open or closed circuit), it must be removed by filtration or by rinsing.

## Experimental Test

To validate the previous theory saying that strong magnetic field increases the proportion of aragonite *vs* calcite, we use X-ray characterization and electron microscopy on the two crystalline forms of calcium carbonate: aragonite and calcite [7].

The aim of this experiment is to calculate the concentration of Aragonite in the mixture without and with applied magnetic field.

The experiment consists in taking two different waters: the tap water and a local mineral water. Here are the characteristics of water samples: Table 1.

Each water is separated into two samples: one remaining intact and the other circulating in a closed circuit with a flow velocity of 1L/min, where a magnetic treatment apparatus containing two NdFeB permanent magnets is installed generating a magnetic field of about 0,3T.

Four types of sample are obtained: normal tap water, magnetically treated tap water, normal mineral water and mineral water treated by the magnetic field. For each type, ten small bottles are filled to take measurements.

The technique used is X-ray diffractometry (XRD) on the two crystalline forms of calcium carbonate: aragonite and calcite. Using a diffractometer, the collected data forms what is called a diffractogram with the peaks of the two crystals:

- Aragonite: 111 and 102
- Calcite: 104

**Table 1:** Tap water and mineral water characteristics

| Parameter | Tap water | Mineral water |
|---|---|---|
| pH | 8.3 | 7.2 |
| Calcium ($Ca^{2+}$) mg/l | 57.0 | 12.0 |
| Magnesium ($Mg^{2+}$) mg/l | 38.6 | 8.7 |
| Potassium ($K^+$) mg/l | 4.2 | 2.8 |
| Sodium ($Na^+$) mg/l | 193.4 | 25.5 |
| Sulfate ($SO_4^{2-}$) mg/l | 96.5 | 41.7 |
| Bicarbonate ($HCO_3^-$) mg/l | 166.0 | 103.7 |
| Chloride ($Cl^-$) mg/l | 347.7 | 14.2 |
| Nitrate ($NO_3^-$) mg/l | 2.2 | 0.1 |

### Figure 3 shows an example of aragonite and calcite analysis using XRD:

Based on the peak area theory which indicates that the integral intensity given by the net surface of the peaks of a phase is proportional to the concentration of the phase in question, the aragonite/calcite ratio can be calculated. This ratio is given by the diffraction lines of each phase.

The coefficient A is then defined as the concentration of the aragonite in the mixture. A is given by:

$$A = \frac{I_{111} + I_{102}}{I_{111} + I_{102} + I_{104}}$$

With, I: integral intensity of a given peak. The result is as follows: As a main result, *A* increases from 29% to 50% (an improvement of 72%). Thus, the calcite which is the main form of calcium carbonate becomes aragonite by action of the magnetic field Table 2 [8].

Similar experimental tests were performed with different configurations (by using electromagnets instead of permanent magnets, changing the arrangement of magnets and the flow velocity) and came out with the same conclusion that magnetic water treatment affects the precipitation of calcium carbonate into aragonite instead of calcite.

However, the final conclusion creates controversy as some studies say that scaling disappears completely by magnetic water treatment while others stipulate that scaling still occurs but in smaller amounts, less compact and removable [9].

### Device installation

Our magnetic device contains two parallel NdFeB magnets. Figure 4 illustrates the proposed configuration of permanent magnets around the pipe: In order to enhance magnetic field inside the pipe, the two magnets are oriented in the same direction (NS-NS) generating an effective magnetic field of 0.3T. Figure 5 presents the magnetic flux density.

The following pictures show the installation of the magnetic device for a domestic water heater (Figure 6):

Magnetic device is mounted on the cold water line at the heater inlet in order to prevent scaling and to increase the life time of the heater.

### Magnetic water benefits on water and equipment

By applying a strong magnetic field, the calcium carbonates (dissolved lime stones) present in the water can no longer crystallize in the form of tartar incrustation.

The water molecules are modified and oriented so that fixing and crystallization of the limestone is no longer possible. The latter will then be transformed into aragonite: a white powder having a very low power of attachment in comparison with that of tartar. The aragonite will be evacuated by the mechanical flow and the low points of the installation.

**Table 2:** Aragonite concentration in the mixture without and with magnetic treatment

| | *A* average without magnetic treatment | *A* average with magnetic treatment |
|---|---|---|
| Tap water | 0.30 | 0.47 |
| Mineral water | 0.27 | 0.52 |
| Total | 0.29 | 0.50 |

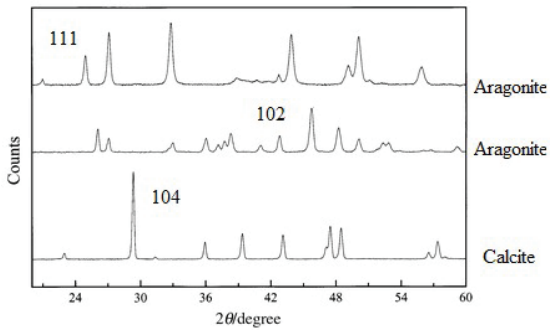


**Figure 3:** XRD graphs for aragonite and calcite peaks

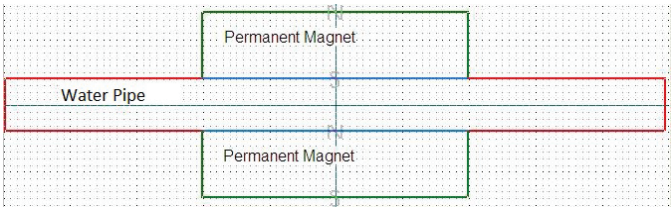


**Figure 4:** Magnetic device configuration

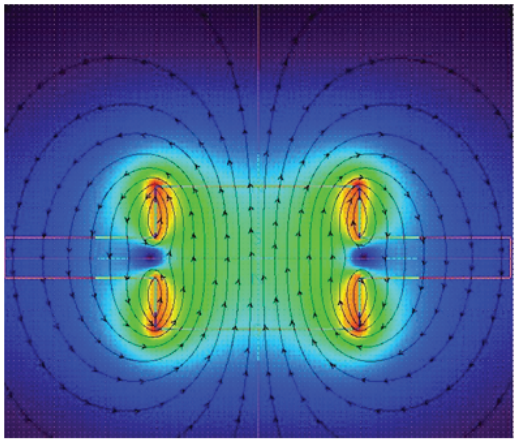

**Figure 5:** Magnetic flux density

**Figure 6:** Magnetic water treatment device on domestic water heater

Thus, all the disadvantages associated with the formation of limestone crystals can be avoided.

As a result, this treatment reduces the use of chemical maintenance products (detergents, softeners, salts, detergents), protects against corrosion, extends the life of the equipment and generates energy savings thanks to the optimized heat exchange.

The water coming out of the tap is perfectly drinkable and prevents tartar. It improves the efficiency of appliances using hot water and reduces the cost of maintenance of the installations.

In the same way, magnetic treatment has positive results on water: it removes odors and improves the taste of water without any intake of salts and toxic residues while retaining the minerals essential to health.

## Conclusion

The main idea of the magnetic treatment of water is to pass water through a strong magnetic field, the calcium carbonate crystals are altered so that they lose their abilities and they can no longer cause scales. This type of process does not use filters or chemicals but uses the power of the magnetic field modifying the characteristics of the water in order to make it more suitable for our use.

These magnetic "filters" have many qualities: they do not require rejecting some of the water that needs to be treated so do not waste water. Indeed, the magnetic treatment only modifies the molecules of calcium and magnesium, so that they do not favor the formation of tartar, but the water retains its calcium content.

Strong and permanent magnetic fields treat water against the harmful effects of limestone without any chemicals and without any energy requirements. They thus make it possible not to produce waste resulting from the use of chemical substances, unlike other types of treatment.

Magnetic water treatment has different applications: it can be used for boilers, electric water heaters, washing machines, dishwashers, swimming pools and irrigation systems.

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