

Comparative testing of limescale products

Task

On behalf of the national homeowners' association, Villaägarna, RISE has conducted a comparative test of five limescale products designed to remove lime or reduce the problems of lime in hard drinking water. The purpose of the test is to obtain objective data showing to what extent the products marketed to households are functional.

Background

In some parts of Sweden, especially in areas with calcareous rocks, the drinking water contains a higher amount of calcium oxide, which gives the water the classification semi-hard or hard.

In Sweden, water hardness is usually stated in German hardness degrees, °dH (°dH = grad deutscher Härte), where 1°dH corresponds to 10 mg of calcium oxide (CaO) per liter of water.

There are slightly varying classifications regarding hardness levels for drinking water, but according to a definition used by the detergent industry the following classes apply:

- 0 – 6 °dH: Soft water
- 7 – 13 °dH: Semi hard water
- 14 – 20 °dH: Hard water
- >20 °dH: Very hard water

Approximately 20 percent of Sweden has semi hard, hard or very hard water. Examples of places in Sweden where such water is found are Skåne, Uppland, Jämtland, Västerbotten, Gotland and Öland. Calcareous water has no known negative health effects, but does on the other hand cause other problems in the form of limescale which results in greatly impaired heat transfer in hot water heaters and can also lead to blockages in thinner pipes. Limescale also causes cosmetic disadvantages in the form of unwanted stains on e.g. glass, or wall and floor tiles.

There are therefore a number of different types of products that claim to be able to remove the lime from the water, or reduce the problems of limescale. The products can be divided into several main groups based on their principle of function:

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1. Traditional water filters that work by ion exchange ("soft water filter").
2. Water purification products in the form of pipes with metal plates inside, which are said to be largely maintenance-free and solve problems with lime in water without the use of salt, electricity or magnets.
3. Magnetic water treaters, which are attached to the water pipe and thus counteract the precipitation of lime.

Tested products

The test has included the following five products available on the Swedish market:

Name	Principle of function
Softening filter NF 13 Commander from Callidus	Traditional water filter for lime. The softening filter is loaded with salt tablets, about 25 kg per month for a household with normal consumption.
Softwater SW34 Special	Water purification products in the form of pipes with metal plates inside, which are said to be largely maintenance-free and solve problems with lime in water without the use of salt, electricity or magnets.
Electrolux Neocal	
Aquabion D20	
Aqua 2000	Magnetic water treater, which is attached to the water pipe and thus counteracts the precipitation of lime.

The tested products were selected and purchased in new condition by the national homeowners' association, Villaägarna, and were delivered to RISE in Borås. The products arrived at RISE on 16 JAN 2019 and they were all in normal working condition upon receipt.

Test method

A test rig with a common inlet and six different outlet pipes was built (see Figure 1-2). In each of the pipes 1-5 there was a product to be tested (P1-P5) in the form of a limescale product, while line no. 6 was a reference pipe without a limescale product.

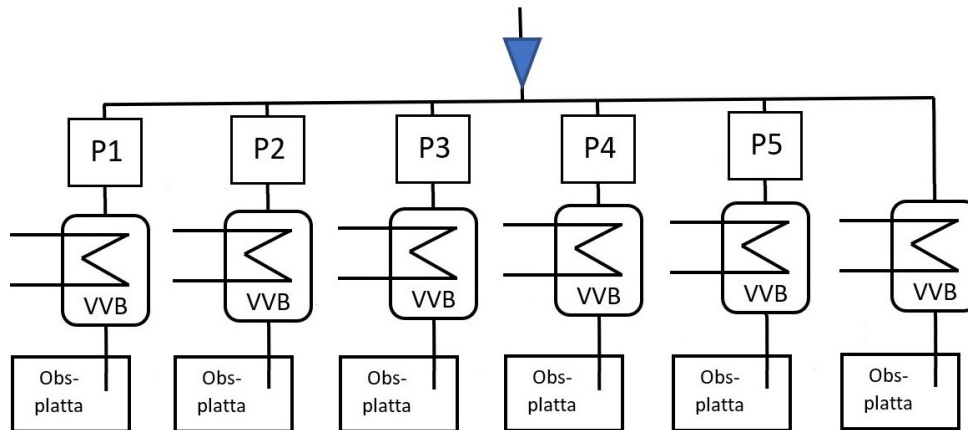


Figure 1: Schematic of the test rig

During a test period of about 2.5 months, cold municipal drinking water with high calcium content (14 German hardness degrees) was allowed to flow through each pipeline with a controlled volume and flow, so that the conditions were the same for all tested products. A chemical water analysis was performed at an accredited laboratory before, during and after the test, demonstrating that the water used had a composition and properties that were stable over time.

After each test product, the water was led into a Nibe Nibette 15 hot water heater with a volume of 13.5 liters, where it was heated from its initial temperature of about 10°C to 60°C. The water flow was alternated between on and off in regular cycles so that the each hot water heater was constantly refilled with new water to be heated, in order to speed up the formation limescale on the heating element. From the outlet of each hot water heater, the water was led

over an observation plate made of black tile, in order to see whether the water caused any visible limescale.



Figure 2: The test rig used for testing in Borås.

At the end of the test period, the hot water heaters were removed and the heating elements were photographed before dissolution of the precipitate. Test product no. 5 (Aquabion D20) is said to convert the lime's chemical structure from calcite to aragonite¹, which should cause less limescale problems than calcite. The underlying reason is that aragonite has a poorer adhesion capacity than calcite and therefore would be flushed out with the water to a greater extent. To verify this effect, approximately 50 mg of samples were taken from this product and from reference pipe no. 6 to perform XRD (X-ray diffraction) analysis of the lime structure.

The heating elements were been put back and the precipitate having formed in each hot water heater was dissolved by filling the tank with about 13 liters of 5% hydrochloric acid solution, which was pumped in and left in the tank for about 30 minutes. Subsequently, the solution was pumped out and the tank was rinsed clean with milli-Q water (ultra-pure water). All the liquid was collected in a plastic can and after dilution, the amount of calcium (Ca) was determined by ICP-OES (Inductively Coupled Plasma Optical Emission Spectrometry). The amount of calcium carbonate (CaCO₃) was then calculated by assuming that all the calcium was available as calcium carbonate.

Test equipment

The test was carried out with a specifically created rig, designed and built at the RISE unit for Energy and Circular Economy in Borås.

The chemical quantification of lime was carried out with ICP-OES (Inductively Coupled Plasma Optical Emission Spectrometry). The measurement uncertainty was estimated at about 20%.

¹ Lime (calcium carbonate) exists as the minerals calcite and aragonite.

Test location and time

The part of the test related to exposure was carried out during the period February to April 2019 in Örbyhus, north of Uppsala, where the municipal drinking water is naturally calcareous and has a hardness of 14 °dH. The chemical analysis of the amount of lime accumulated in the hot water heaters was carried out in May 2019 at the RISE Unit for Chemistry and Materials in Borås and the XRD analysis was performed at the RISE Unit for Chemistry and Materials in Stockholm.

Results

The results below apply only for the tested products.

The table below shows the calculated amount of calcium carbonate in the precipitate formed in the hot water heater after each tested product. Figure 3 shows images of the precipitation on the different heating elements.

According to the result, the traditional water filter (Callidus NF 13 Commander) managed to separate practically all lime in the water. For Softwater SW34 Special, the results show that the lime precipitation was slightly less than half the value of the reference without limescale separation, while the other tested products were at a level that is within the measurement uncertainty from the reference value.

Test no.	Tested products	CaCO ₃ (mg)
1	Softening filter NF 13 Commander from Callidus	20
2	Softwater SW34 Special	2,300
3	Electrolux Neocal	4,500
4	Aqua 2000	6,700
5	Aquabion D20	6,500
6	Reference (no limescale separation)	5,400

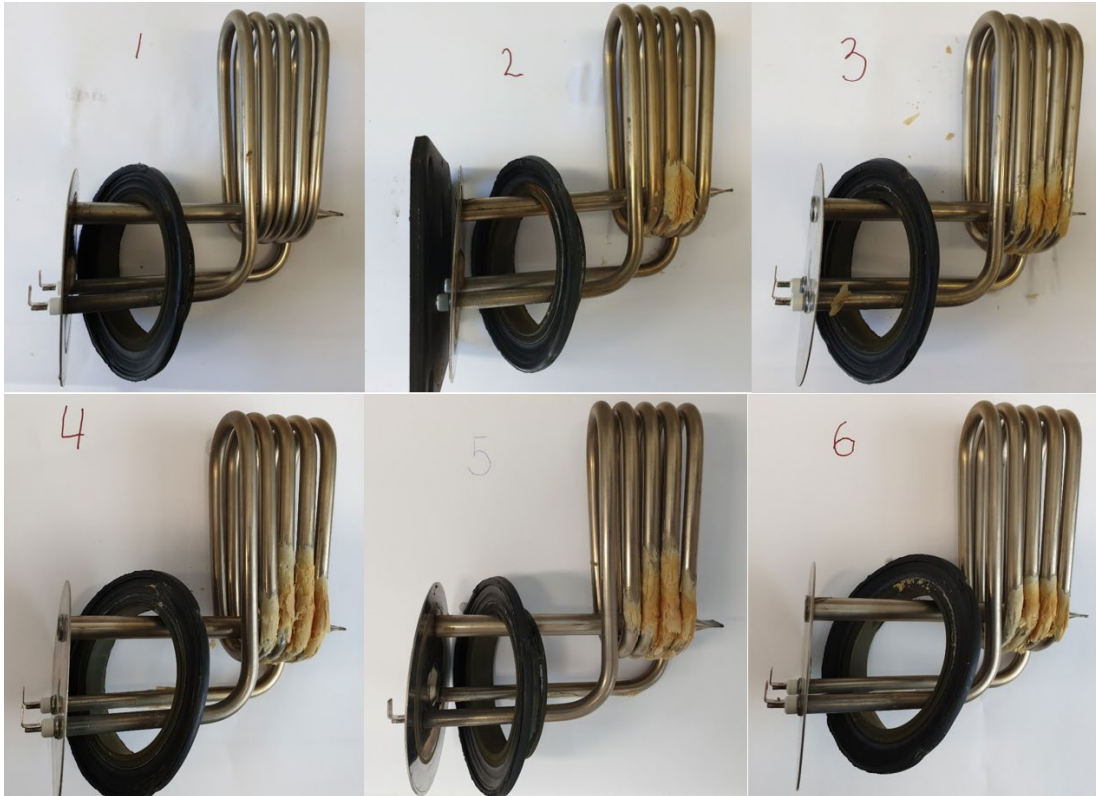


Figure 3: Heating elements with lime precipitation before quantification

The results of the XRD analysis, in which samples from Aquabion D20 were compared with the reference, show a perfect agreement with calcite for both samples, and display no conversion to aragonite, cf. Figure 4.

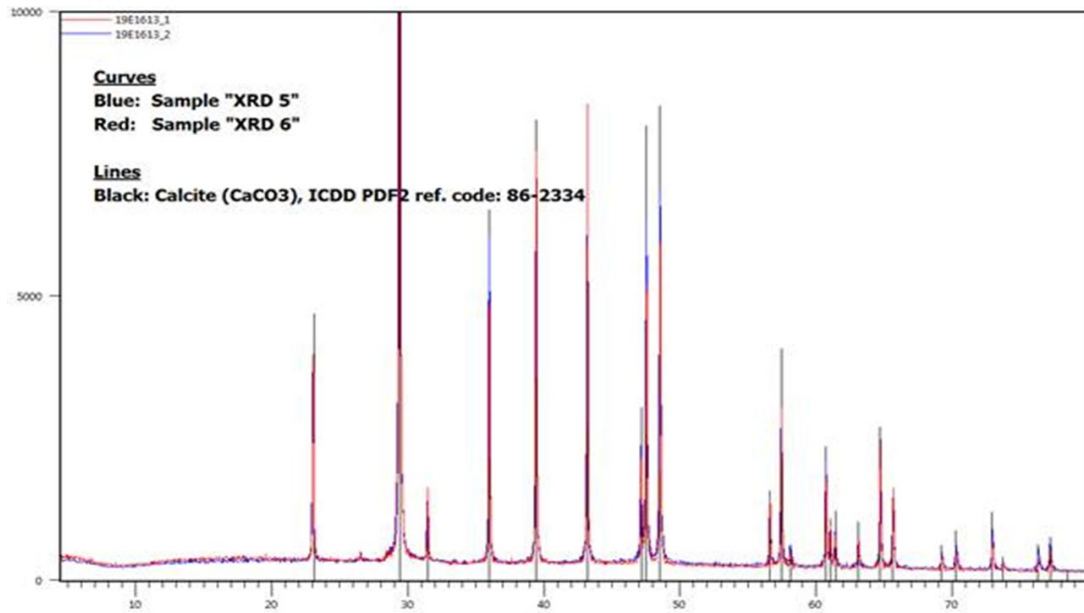


Figure 4: Results from XRD analysis for Aquabion D20 (XRD 5) and reference (XRD 6) and comparison with spectra for calcite

Figures 5 and 6 show images of the observation plates after 1 and 2 months of exposure, respectively. The images display that there was rapidly a significant difference between the amount of lime deposits from the Callidus filter (no. 1), where no lime deposits are visible at all, compared to other products (no. 2-6). This confirms the result of the quantification of precipitates in the hot water heaters.

For the other plates (nos. 2-6), it is difficult to draw any clear conclusions. The deposits have slightly different shapes and appearances, but this can also be due to differences in how the water flow came in contact with the plate.

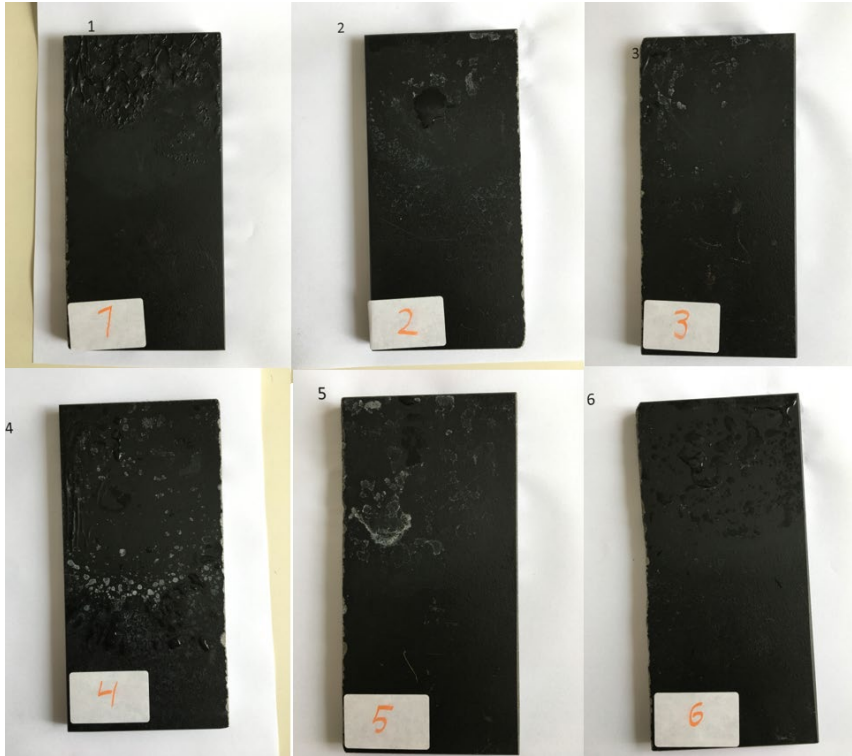


Figure 5: Observation plates after 1 month of exposure

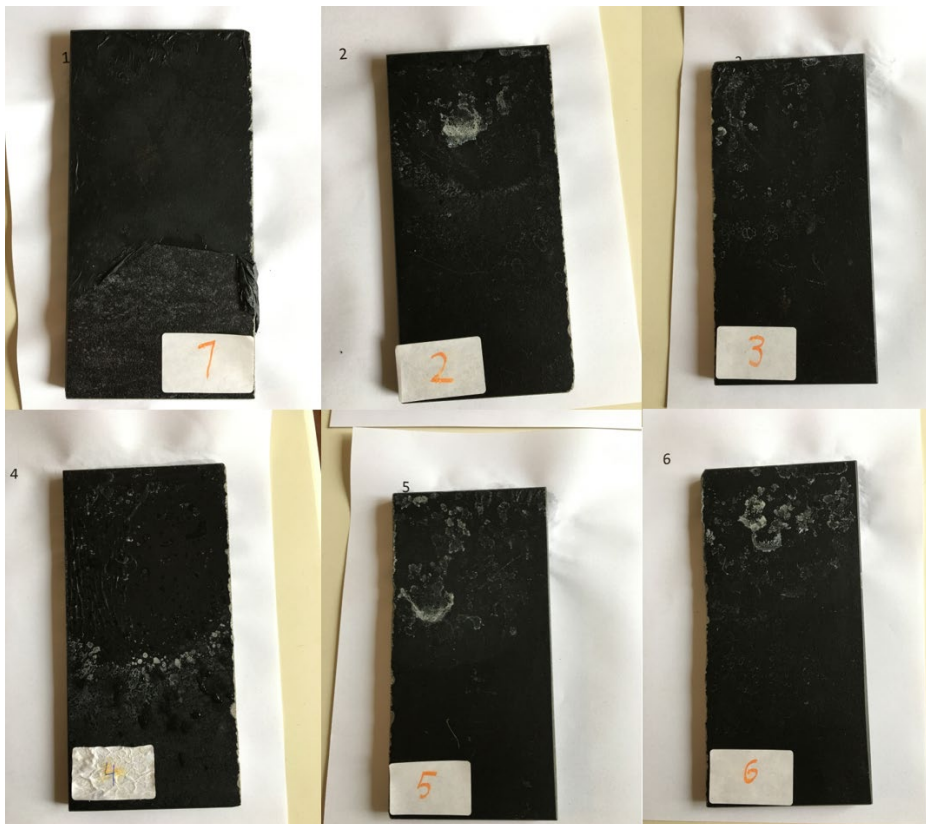


Figure 6: Observation plates after 2 months of exposure

Conclusions

The results of the test show that the traditional water filter (Callidus NF 13 Commander) is the tested product that by far has the best effect with regard to limescale separation, since the water filter succeeded in separating practically all the lime from the water. This product also eliminates problems with visible lime deposits from the water.

For Softwater SW34 Special, the result shows that the lime precipitation was slightly less than half the value for the reference without lime separation, while the lime precipitation was around 100 times lower than for Callidus NF 13 Commander. Electrolux Neocal, Aqua 2000 and Aquabion D20 are at a level that is within the measurement uncertainty for the reference value, i.e. no lime separating effect could be detected for these products.

The marketing claims that Aquabion can reduce the calcium deposits by converting the lime in the water from calcite to aragonite, which has a poorer adhesion capacity than calcite and therefore to a greater extent can be flushed out with the water. The alleged effect of Aquabion D20 in converting the lime structure from calcite to aragonite is contradicted by the analysis result, since the sample taken after this product still shows perfect consistency with calcite.

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