

Effect of the electromagnetic water treatment on the carbonate scales. Determination of calcite and aragonite by the Meigen test

INTRODUCTION

- Calcium carbonate deposits cause technical and economic problems such as scaling of water heaters.
- Electromagnetic (EM) techniques is used in water treatment to avoid the scale on domestic pipes.
- The influence of this techniques on the crystalline form of the scaling has been observed. The crystallisation appears mainly as aragonite rather than calcite with EM treatment. Aragonite crystals are less predisposed to form calcareous scaling and revert to calcite over time (Coey and Cass 2000).
- Distinction between calcite and aragonite could be performed in a simply way with the Meigen test (Friedman 1959), adding cobalt nitrate solution and boiling (Pueyo and Alonso 1991):
 - ✓ Calcite remain white (unaltered) (Figure 1 left).
 - ✓ Aragonite took on a purple colour (Figure 1 right).
- The Meigen test involves solid samples and the applicability to water treatment is limited.

APPLICATION OF ELECTROMAGNETIC TECHNIQUES IN WATER

- The TK3K EM equipment was designed by ECOTÉCNICA ENERGY SYSTEMS S.L. The experimental set up with TK3K was used with a recirculation of 4 hours. Synthetic solution was prepared by dissolving 2 g of calcium carbonate with CO₂ in 4 L bi-osmotized water.
- EVAPORATION AT ROOM TEMPERATURE (23 ± 2 °C): The formation of crystals with and without EM treatment was studied, after evaporation for 135 days of the two obtained water samples, when surface crystals were formed. Conclusions of the XRD and SEM analysis of these samples: EM treatment produced a greater quantity of aragonite crystals, which persisted despite the elapsed time (untreated 50 % aragonite and treated 80%).
- EVAPORATION IN OVEN AT DIFFERENT TEMPERATURES (Figures 2 and 3).
 - ✓ At 70 and 105 °C: Higher percentages of aragonite were observed in both samples, indicating that higher evaporation temperatures induce aragonite formation. This has been observed in a scale obtain in a water heater, with 100 % of aragonite.
 - ✓ At 25 and 40 °C: Differences between EM and without EM can be observed: calcite concentration was higher without treatment (30-55 %) and aragonite samples with EM treatment (80-84 %)
- These facts are according with Coey and Cass (2000): The crystallisation appears mainly as aragonite rather than calcite with EM treatment.

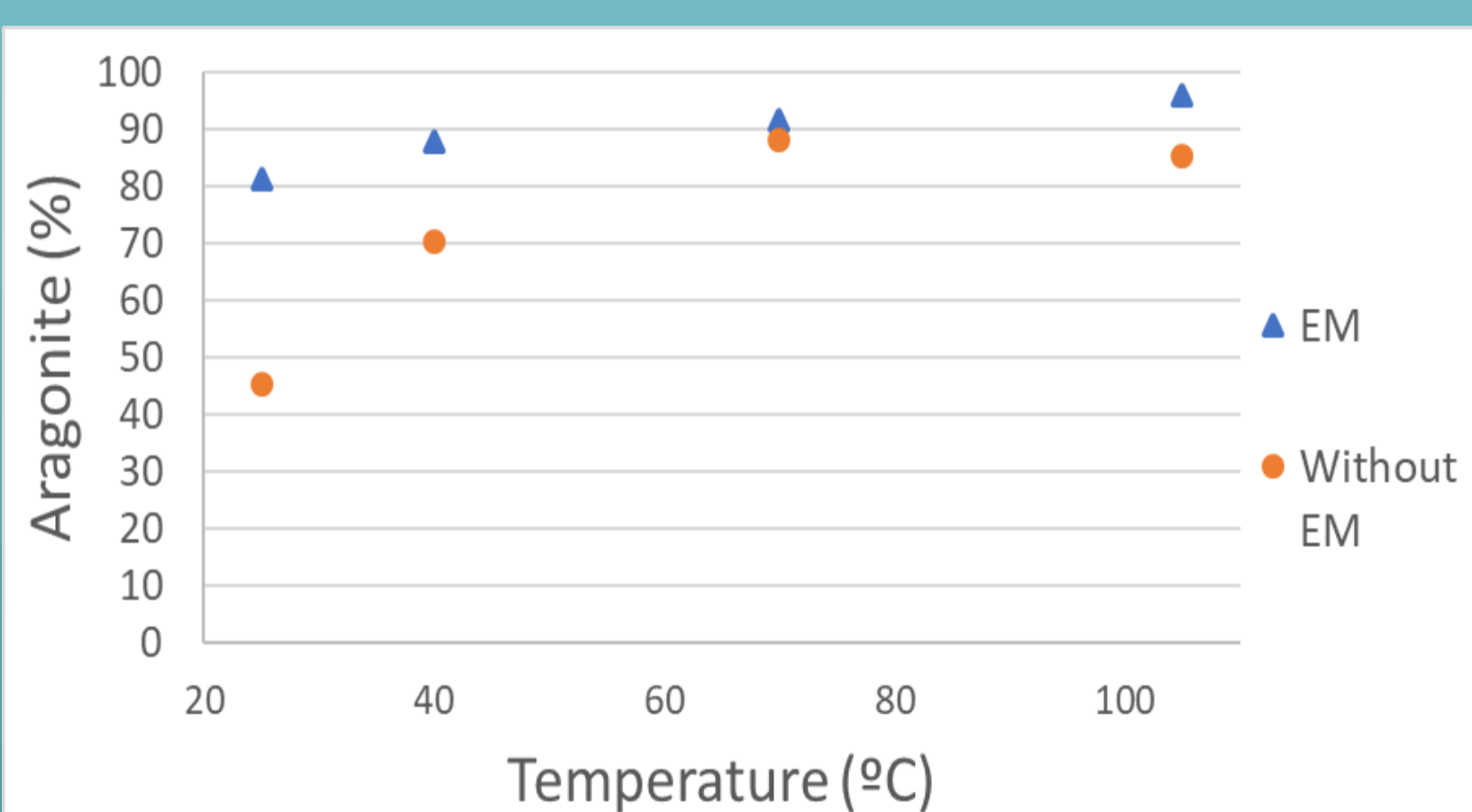


Figure 2: Aragonite (%) vs temperature with and without EM.

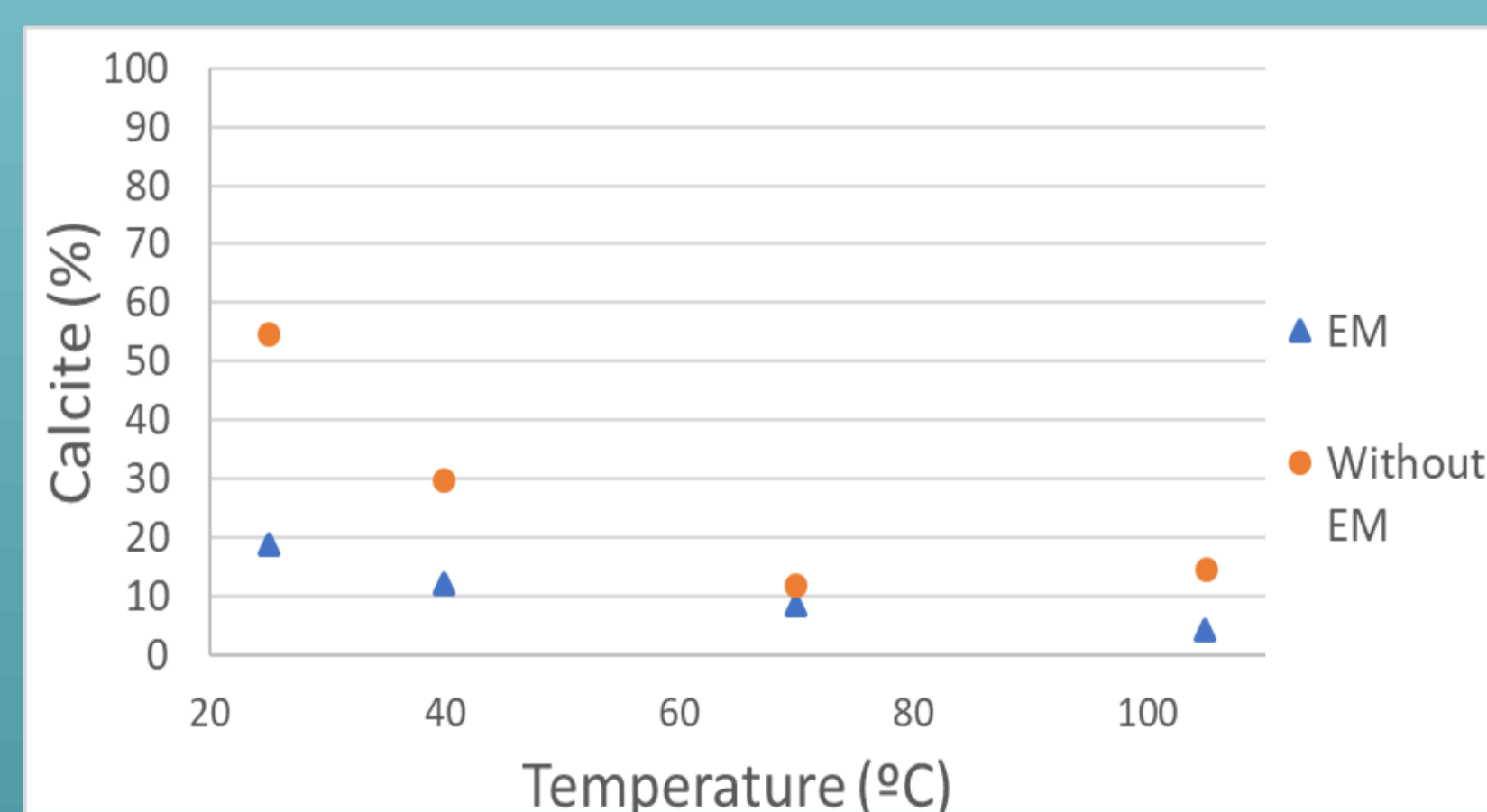


Figure 3: Calcite (%) vs temperature with and without EM.

OBJECTIVE

To determine the effects of TK3K equipment on the formation of calcite/aragonite, using SEM and XRD, and to analyse the applicability of the Meigen test on crystals obtained from water, with a study of the interferences.

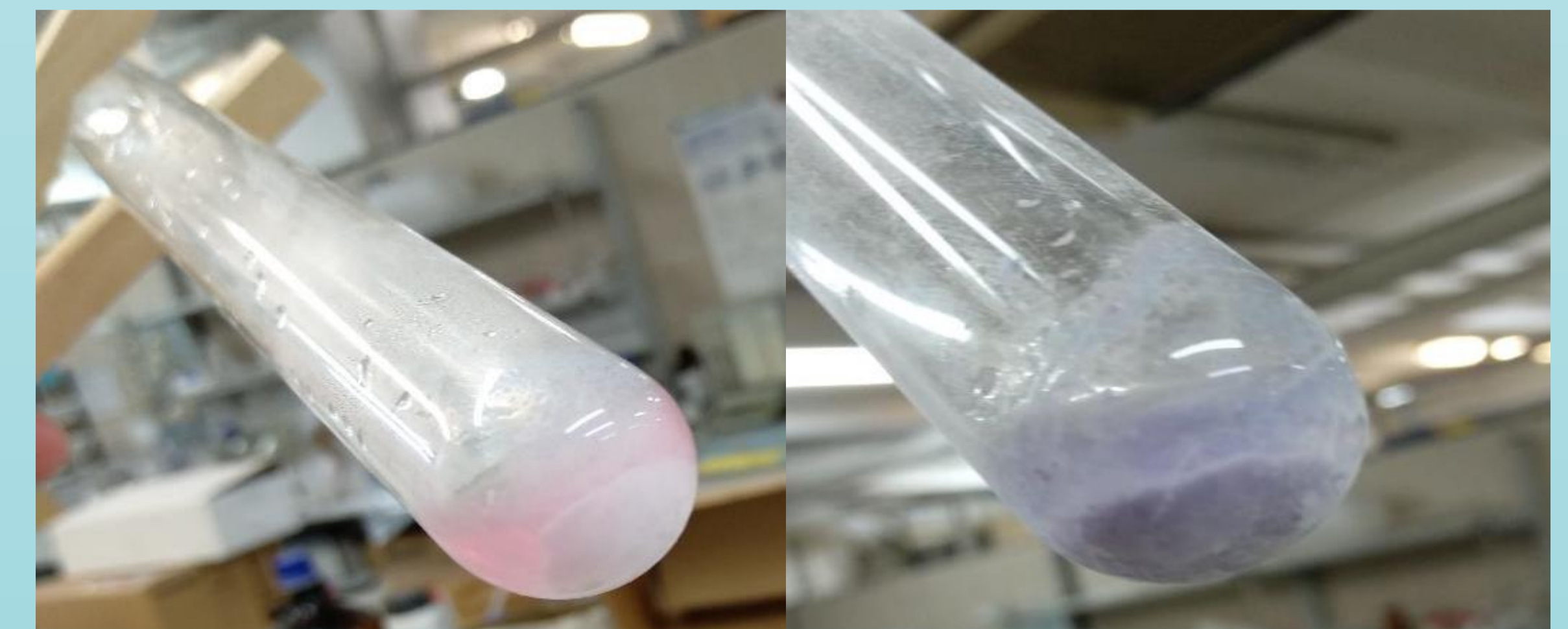


Figure 1: Calcite (left) and aragonite (right) treated with Meigen's test

MEIGEN TEST STUDY AND INTERFERENCE ANALYSIS

- The test was applied to different samples: mineral samples, commercial calcium carbonate and crystals from evaporation experiments. The expected colorations were obtained.
- Other ions are present in tap water, which produce interferences and complicate the identification of calcite and aragonite:
 - ✓ Chlorides can cause a blue coloration due to the formation of the tetrachlorocobaltate(II) ion.
 - ✓ Excessive alkalinity could cause a blue-green precipitate, so if the pH of the solution rises above 8, the precipitation of cobalt hydroxide is promoted.
 - ✓ Ammonium causes a yellow coloration due to the formation of the hexaamminecobalt(II) ion.
 - ✓ Oxidising agents causes a dark brown colouration, because cobalt(II) is easily oxidised to cobalt(III).
- Meigen test is not infallible. If the samples are fine-grained, the solution can mask the white colour of calcite. The use of ammonium sulphide can turn the aragonite black (Jirová 1956) (Tamer 1965).

CONCLUSIONS

- The amount and type of crystals formed after the application of the TK3K equipment is highly dependent on temperature.
- At room temperature (23 ± 2 °C) for 135 days, after the application of EM techniques: 80 % of the crystals were aragonite, which had long time to reversal to calcite.
- At 70 and 105 °C, a greater number of aragonite crystals were observed with a reduction in calcite crystals in both samples.
- At 25 and 40 °C, calcite percentage was higher in samples without treatment (30-55 %) and a greater percentage of aragonite was obtained in samples with treatment (80-84 %).
- Meigen test could be an excellent option as a technique complementary to XRD and SEM. It is a simple, cheap and quick analysis prior to determination by instrumental techniques.
- The presence of colours other than violet or white in crystals from tap water is a symptom of interferences in the determination with Meigen test.

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