NOVEL REACTOR WITH MULTIPLE ZINC ELECTRODES FOR SCALE PREVENTION

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Abstract
The use of zinc reactor system with multiple electrodes was studied. Physico-chemical analyses of water and X-ray powder diffraction (XDR) of scale were performed without treatment and after the water passed through the reactor. The results showed that chemical parameters were remained the same after the treatment. Very small concentration of Zn^{2+} was detected in water after the treatment. The XRD analyses showed that in drinking water the share of calcite was higher, while only aragonite was formed after the treatment.

Introduction
Carbonate $CaCO_3$ precipitation in drinking water is a crystal mixture of calcite and aragonite at certain ratio between them. The share of calcite is affected by temperature, pH, ion concentration and suspended solids
In our previous study it was proved that Zn substantially inhibited the nucleation rate of $CaCO_3$ [1]. Crystallization of aragonite $CaCO_3$ was studied [2]. It was discovered that the morfology of carbonate precipitate differs a lot upon the crystal structure. Recently, a lot of efforts have been done to generate green inhibitors, either from plant extraction or by using natural organic molecules. [3] However, it is complicated if chemicals are added directly into the water and could affect the chemical water quality.
The main objective of the present research, was to study the effect of reactor with multiple Zn electrode on scaling and $CaCO_3$ crystal morphology was studied. The calcite/aragonite ratio was studied by means of a chemical analysis and X-ray powder diffraction. A mechanism has been proposed that the surface reaction of Zn-ions with $CaCO_3$ might be rate determining step in the crystallization process.

Experimental
Untreated water samples were taken from waterworks (Maribor, Slovenia). Water flowed through the Zn-reactor (Figure 1) directly from the water pipe. The sample was taken at the outflow from the reactor. Samples of untreated and treated waters were saved for chemical and XRD analyses.
The device in Figure 1 operates due to certain potential difference which is governing the process of scale prevention. Inside the reactor there are multiple zinc electrodes as seen from Figure 1. Due to potential difference the device inhibits the scale formation. For the proper working the ratio between zinc versus copper electrode area (Szn/Scu) is very important.

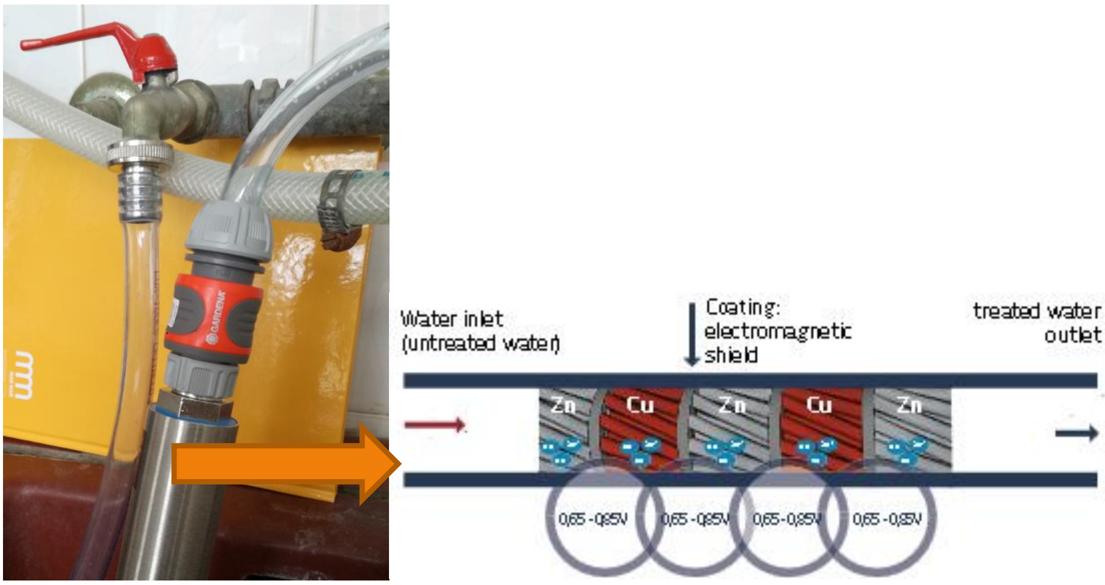

Figure 1. Zinc reactor

The chemical analysis of water was made in three replicates. The standard methods are gathered in Table 1.

Table 1. The methods used for water analyses

Parameter	**Standard method**	**Apparatus**
T **(°C)**	ISO 10523	Thermometer
pH	ISO 10523	pH-meter, MA 5740
TH **(°d)**	38409-H6 (1986)	Titration
Ca^{2+}, Mg^{2+} (mg/L)	38406-E3 (1982)	Titration
Zn^{2+}, Cu^{2+} (μg/L)	ISO DIN 11885 (1993)	ICP-MS/Perkin Elmer Elan 6000

X-ray powder diffraction data were collected with an AXS-Bruker/Siemens/D5005 diffractometer, using Cu-Kα radiation at 293 K. The samples were scaned with positin sensitive detector and measured in range 10°<2Θ<80, with the step of 0,01 and scanning speed of 2 s per step. Determination of phases in the sampe was done with Search/Match program.

Results and discussion

Water was taken after passing through the Zinc reactor. Results of chemical analyses are shown in Table 2.

All experiments were performed at room temperature.

Table 2. The methods used for water analyses

Analysis	Drinking water	Treated water
T(°C)	20	20
Ca^{2+} (mg/L)	65,7	65,7
Mg^{2+}(mg/L)	21,3	21,3
Zn^{2+}(mg/L)	< 0,01	< 0,01
Cu^{2+}(mg/L)	<0,01	<0,01
***TH* (°d)**	14,1	14,1

It is clearly seen that chemical water quality remained the same after the treatment. Also none of the Zn concentration difference was noted. Copper concentration was also measured due to the content of the reactor. The concentration in drinking water was below 10 µg/L.

XRD analysis of scale formed in untreated water and in treated water was performed. The diffractogram of the precipitate from untreated water showed some calcite crystals peaks (denoted C in Figure 1a). Zinc reactor device induced changes to the crystal morphology and promoted crystallization in the aragonite rather than calcite. Only aragonitae in powdered form was formed after the treatment (Figure 1b).

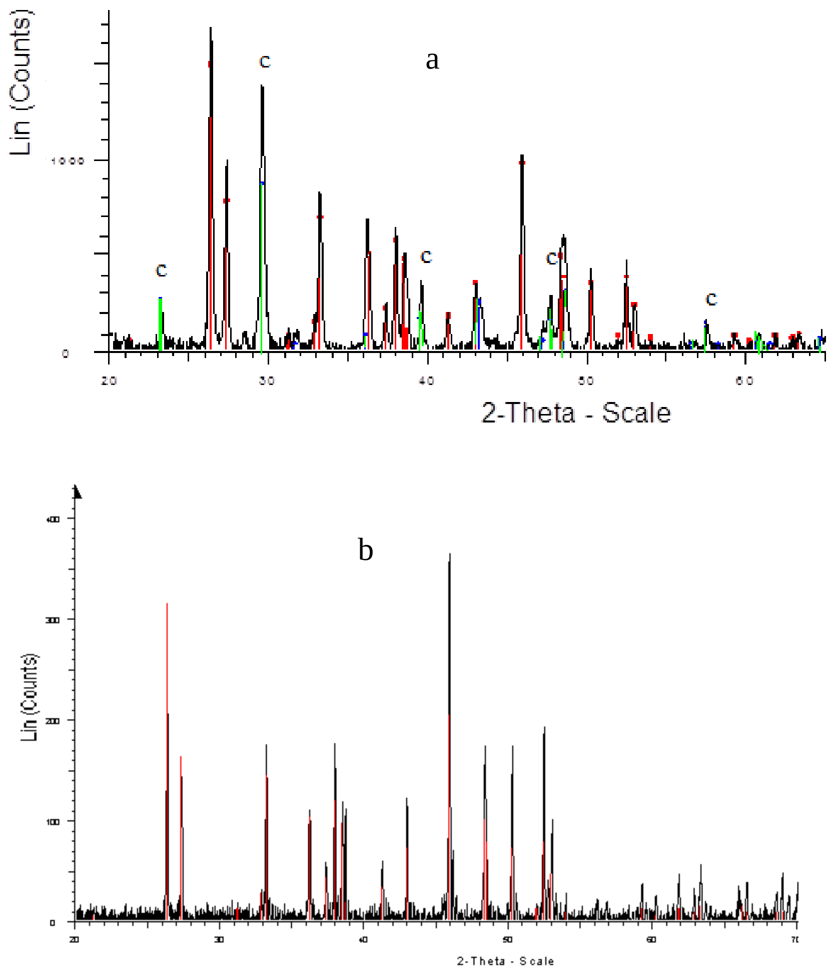

Figure 2. XRD analysis of $CaCO_3$ (a pattern denotes the untreated water, b treated water)

Since the product is novel, the operating time of reactor could be estimated at 10 years according to the results. Due to calcite formation inhibition the pipes are preserved and there is prolonged the lifetime of pipes. Further, no chemical cleaning is needed for scale removal inside the entire water pipeline system. Therefore, device minimizes operational costs.

Conclusion

The trace amounts of Zn substantially inhibit the nucleation rate of calcium calcite. The Zinc concentrations below 10 μg/L enable the formation of aragonite and disable the formation of calcite. Already after analyses of the scale it was found the powdered form of aragonite was formed.

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References

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