



Effects of magnetic treatment on scaling power of hard waters



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ABSTRACT

The main purpose of this study was to investigate the effects of a magnetic treatment on the scaling power of hard waters using a non-electrochemical scaling method. The influence of this treatment on the calcium carbonate precipitation was confirmed. Experimental results showed that the scaling potentiality of the treated water was significantly inhibited by the applied magnetic field. The anti-scaling efficiency of the applied permanent magnets was about 45%. The rapid controlled precipitation (RCP) tests confirmed that the magnetic field produces a “memory effect”. The anti-scaling properties of the treated water were retained for approximately three days following the magnetic treatment.

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1. Introduction

Scaling in natural hard water is a major concern in different facets of industrial processes and domestic installations [18,22,28]. Scale deposits by natural waters often lead to numerous technical and economical problems in industrial plants and domestic equipment by blocking the flow of water in pipes or limiting heat transfer in heat exchangers [14].

Different traditional chemical methods have been used for scale prevention, either the pre-precipitation of the scale former with lime or soda ash, the addition of chemical inhibitors, or the replacement of the scale former with soluble ions by ion exchange. These methods are effective, but they can be expensive and can substantially change the water chemistry. Environmental and economical considerations are strong motivations underlying the development of methods which would prevent hard scales just by modifying the way of precipitation [23]. Therefore, various physical methods were developed to avoid chemical addition, namely magnetic water treatment (MWT) methods of hard waters which are currently used to prevent scale buildup. They were developed to substitute chemical water treatment methods which use products harmful to the environment and human health [2]. The anti-scale magnetic treatment of hard waters is used to prevent the buildup of deposits on the walls of industrial systems, in particular in heat exchangers, as well as in domestic equipment [1,25]. They have been applied as a scale deposition controlling and/or preventing tool in water systems for several decades [29].

Over the last few decades, a number of magnetic devices have been conceived in order to reach good anti-scale prevention efficiency.

Despite its ubiquity, there is relatively little literature on MWT. It is not clear how it works or even whether it works or not. Unlike chemical water softening, MWT should have no direct effect on water chemistry. It is claimed to alter the morphology and adhesion of calcium carbonate scale [9]. The efficiency of this treatment is still a controversial question and it is not possible to get a clear explanation of the phenomenon [1,4,5]. Published data are often contradictory. While some authors [15,27] report about scale reduction by MWT, some others have found only minor or non-influence [8]. In addition there is a dispute on whether the deposits of calcium carbonate from magnetically treated water are predominantly calcite or aragonite [9]. A great number of experimental researches were carried out on the modification of the calcium carbonate precipitation process by MWT.

Various methods were used to estimate the scaling power of natural waters and characterize the scaling formation mechanisms. These methods can be roughly divided into two categories: electrochemical methods and non-electrochemical methods. In the former, the scaling rate can be evaluated from the decrease of the electrochemical current intensity [20], by measuring the deposited mass, or even by performing electrochemical impedance analysis [10,13]. Some of the non-electrochemical methods consist in forcing the calcium carbonate precipitation by increasing the pH. Some others are based on the heating or evaporation of the solution [1,12].

Our goal was to experimentally examine the effect of a magnetic treatment on the scaling potentiality of hard waters by means of a non-electrochemical scaling test.

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2. Material and methods

2.1. Water treatment

Experiments were conducted in a brick factory located at El Hamma - Gabes (South-east of Tunisia). The experimental study was carried out using permanent magnets, model GMX 8000. The applied magnetic devices were tested in a real-scale study. Two pairs of MWT devices with north and south faces facing each other were associated at a PVC tube. In this configuration, the magnetic induction was perpendicular to the water flow. The characteristics of the magnetic device used in this study are illustrated in Table 1.

2.2. Water characteristics

Water samples were collected, before and after passing through the magnetic field, in 1 L polythene bottles. Physico-chemical analyses were performed on the magnetically treated and the untreated water. Hardness, calcium (Ca^{2+}), magnesium (Mg^{2+}) and bicarbonate (HCO_3^-) were analyzed according to the AFNOR standards. Temperature, pH and electric conductivity (EC) were measured.

2.3. Precipitation test

In order to evaluate the scaling power of water, the precipitation of calcium carbonate (CaCO_3) was induced following the rapid controlled precipitation (RCP) method. This method was proposed by Lédion et al. [21]. It consists in degassing of CO_2 from the test water by a moderate agitation using a magnetic stirrer. In this way, the nucleation and the growth of CaCO_3 are initiated in a similar way to the natural scaling phenomenon. The water scaling potentiality is then characterized by taking measurements of pH and resistivity as a function of time. The experimental set-up of RCP is illustrated in Fig. 1. Parallel tests were performed on samples taken at the same time. The magnetically treated water and the untreated water were stirred simultaneously at a speed of 600 rpm. The pH and the resistivity of the two waters were measured every 5 min. The whole experimental test lasted for 100 min.

The start of precipitation is indicated by a change in slope of the resistivity-time curves, while the slope beyond the inflection characterizes the kinetics of the CaCO_3 precipitation. According to Liu [24], the onset of precipitation is determined more accurately from the pH curves. The resistivity curves are used essentially to analyze the rate of reaction.

In order to evaluate the anti-scaling efficiency of the applied magnetic water treatment, the area between the resistivity curves for the magnetically treated water and reference water (untreated water) was compared to the area beneath the resistivity curve for the untreated water. The efficiency, E , was defined by the following equation [24]:

$$E (\%) = \frac{\int_0^t (\text{RNT} - \text{R}_0) dt - \int_0^t (\text{RT} - \text{R}_0) dt}{\int_0^t (\text{RNT} - \text{R}_0) dt} \times 100 \quad (1)$$

where R_0 is the initial resistivity; R_{NT} and R_t are the resistivity of the non-treated water and the treated water at time t , respectively.

In order to prove and evaluate the memory effect of the magnetic field (persistence of the anti-scaling properties of the treated water after a magnetic treatment), RCP tests were conducted on the treated and untreated water during 5 days following a magnetic treatment. One RCP test was performed per day. The comparison between pH-time and resistivity-time curves of treated water and that of untreated water allows verifying that the anti-scaling capacity of the magnetically treated water persists for some time after the treatment.

3. Results and discussion

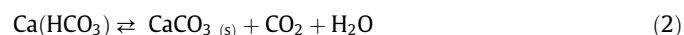
3.1. Effect of magnetic treatment (MT) on water characteristics

Average characteristics of the treated and untreated water are reported in Table 2. Chemical analyses showed that the water used in the experimental study was very hard; the mean hardness value was about 213 °F. The average contents of calcium and magnesium in the tested water were 600 and 213.12 mg/L, respectively. These contents explain the high hardness of the groundwater used in the investigations, which is due to the limestone aquifer that is the principal type of groundwater aquifers in the south of Tunisia.

Furthermore, results showed that the magnetic treatment has no effect on the chemical characteristics of the treated water. Indeed, chemical parameters of the magnetically treated water had practically the same values as those of the reference water. This means that the MWT do not modify the chemical composition of the treated water. According to Gryta [16], unlike chemical water softening, a magnetic treatment should have no direct effect on water chemistry. It is claimed to alter the morphology of calcium carbonate scale [9,19,23].

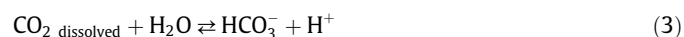
3.2. Effect of MT on the scaling power of water

The scaling potentiality of the tested waters was evaluated using the RCP method. Fig. 2 depicts the variation of pH and resistivity of the treated and untreated water versus time during the RCP test. The main reaction involved in the precipitation of calcium carbonate is governed by the displacement of the calco-carbonic equilibrium (2):



As the dissolved CO_2 content decreased due to water agitation, the solution tends to restore equilibrium (2) by the shift toward CaCO_3 precipitation.

The increase of pH values observed during the RCP tests (Fig. 2) can be explained by the following reactions:



The equilibrium reactions (3) and (4) were towards the left because of the CO_2 departure, so the concentration of OH^- ions increased and consequently the pH values increased. As soon as the critical super-saturation was reached, the nucleation and the growth of calcium carbonate were initiated and the pH began to decrease because of the liberation of H^+ ions according to reaction (5):



Table 1

Technical specifications of the permanent magnet GMX 8000.

Dimensions (L × W × H)	0.127 m × 0.127 m × 0.120 m
Device weight	3.628 kg
Electrical power source	None
Water temperature	273.15–422.038 K
Life expectancy	Minimum 125 Years
Construction	Heavy duty steel
Protective coating	UV rated poly vinyl chloride (Rubber)
Magnetic field strength	0.8 T (tesla)
Magnetic power source	Strontium ferrite permanent ceramic
Ambient air temperature	227.59–422.038 K
Tubing or pipe	0.0762–0.2032 m

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