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On reduction in the surface tension of water due to magnetic treatment

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Abstract

Water treatment by magnetic field (MF) or physical water treatment (PWT) is an attractive but still controversial issue. The main purpose of the present study was to investigate whether or not a physical water treatment reduces the surface tension of water as reported in some scientific literature. In this paper PWT phenomenon was studied by measuring surface tension of treated and untreated waters. More than 200 tests were done during a six month period in various conditions to evaluate the validity of the observed phenomenon. The test results showed that surface tension of water is too sensitive to experimental conditions to be considered as a safe and reliable indicator for studying the effects of magnetic field on water. It was found that meaningful changes in surface tension of a liquid sample after a day can be a good indicator for presence of physical or chemical changes in the sample.

Keywords: Magnetic field; Physical water treatment; Surface tension; Reduction

1. Introduction

Investigation on effects of magnetic field (MF) on water is still a controversial subject. The contradictory reports on the performance of magnetic devices on water imply that they are only effective under some certain conditions on some aspects of waters encountered in a specific industry.

The available literature on MF water treatment can be classified in upstream and downstream effects as follows [1]:

Upstream effects

- Mechanism of MF action
- Effect of water chemistry and its impurities
- Effect of hydrodynamic parameters (geometrical factors of the treating system, velocity...)
- Effect of MF arrangement
- Nucleation process (effect of impurity, frequency and growth of nuclei)

Downstream effects

- Changes in the properties of treated water (conductivity, pH, surface tension...)
- Zeta potential of the produced calcium carbonate particles
- Morphology of precipitated calcium carbonate (size, shape)
- Produced new entities (free radicals, reactive agents...)
- Suppression of the rate of scale formation

Literature survey about the subject indicates that most authors were interested in downstream effects of magnetic treatment of water especially the morphology of precipitated calcium carbonate. Many researchers believe that MF actually has an efficacy on the morphology of precipitated calcium carbonate [2–7]. Some researchers reported that magnetic treatment affects water properties such as light absorbance, pH, zeta potential and surface tension [8–11]. However, these effects have not been always confirmed [12,13]. A few studies can be found that focused on the phenomenology of Magnetic field [7,14,15].

Chibowski et al. [10] reviewed the literature on MF treatment and carried out tests on MF effects on in situ precipitated calcium carbonate in especially well defined and controlled system and conditions. They found that their results support some of MF effects reported in the literature but disagree with some others. They concluded that still more experimental evidences have to be collected for verifying the controversial hypotheses dealing with mechanism of magnetic field. Therefore, it seems many acknowledge that the MF phenomenon merits for further study. In this work more than 200 oriented tests have been done in various conditions in a six month period to investigate the validity

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of reduction of surface tension of water due to MF treatment. Recent contribution of Cho and lee [11] in correlating the reduction of surface tension of water due to physical (MF) treatment and fouling control of heat exchangers seems doubtful and it encouraged us to present these experimental results.

2. Experimental design

2.1. Magnetic treatment

A commercial magnetic conditioner, GMX model 400, was used to study the effect of magnetic treatment on tap and pure water. Pure water was deionized water with resistivity of 18.2 MΩ cm, prepared with an Elix 5 followed by a Millipore ultra water purification system. The conditioner consisted of 4 magnets of grade 8, Strontium Ferrite permanent ceramic. Size of each magnet was 2″ × 1/2″ × 1/2″ with minimum strength of 3850 Gauss. Water was physically (magnetic) treated by passing in a 3/4″ plastic pipe through the conditioner as shown in Fig. 1.

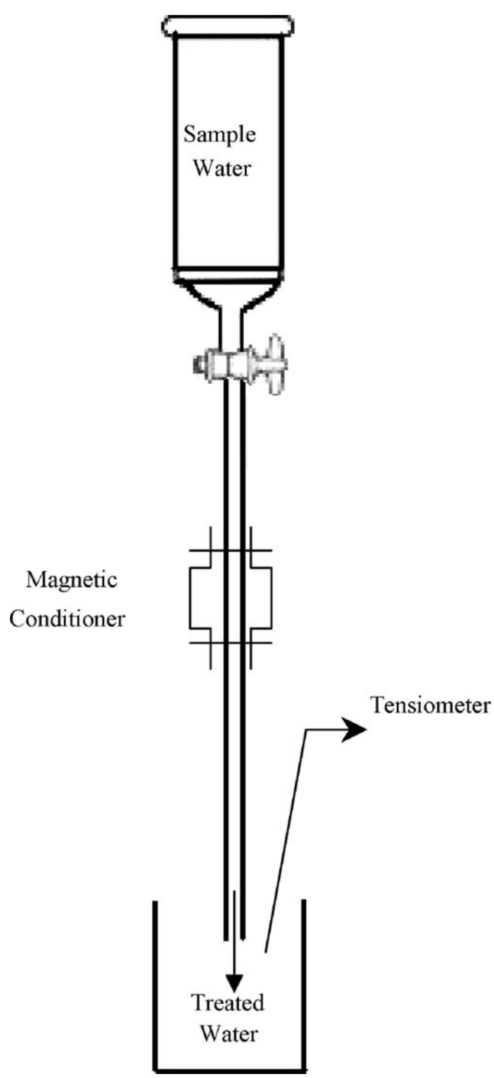

Fig. 1. Experimental arrangement for the magnetic treatment of water and outline of analysis.

The length of plastic pipe, MASTERHEX 06401-16, TYGON® manufactured by Saint-Gobian, was 1.10 m.

2.2. Surface tension measurement

It was done by using *Processor Tensiometer K-12* version 5.05 Kruess GMBH—Hamburg, using Du Nouy ring. All measurements were carried out at room temperature (20 ± 1 °C). The following points were cared in each surface tension measurement

1. The tensiometer was calibrated by pure water every often.
2. The Du Nouy ring was cleaned before each measurement.
3. The weight of cleaned ring was checked time to time with tarred balance of the unit. It was usually 0.2–0.5 mg.
4. Magnetic stirrer was not used for avoiding any contamination.
5. All measurements were done by single method and semi-automatic mode.
6. It was found that the measured value depends slightly on the depth of dipped ring; therefore a fixed depth was chosen by turning the height control knob around 45° after the ring touched the liquid surface.
7. Each surface tension measurement usually took about 8 min after preparing the samples.

3. Results

It was found that the surface tensions of both tap and pure waters depend on frequency of magnetic treatment. Due to reproducibility, only the results of measurements for pure water were reported in this paper. Fig. 2 shows the effect of number of magnetic treatment (frequency) on surface tension of pure water. MF treatment of tap water also resulted in the similar trend of reduction in surface tension. This figure shows clearly that surface tension of water approaches to a certain value after a few treatment cycles. This trend of changes (reduction at the beginning and then becoming constant) in surface tension of MF treated water was also reported by other researchers [11].

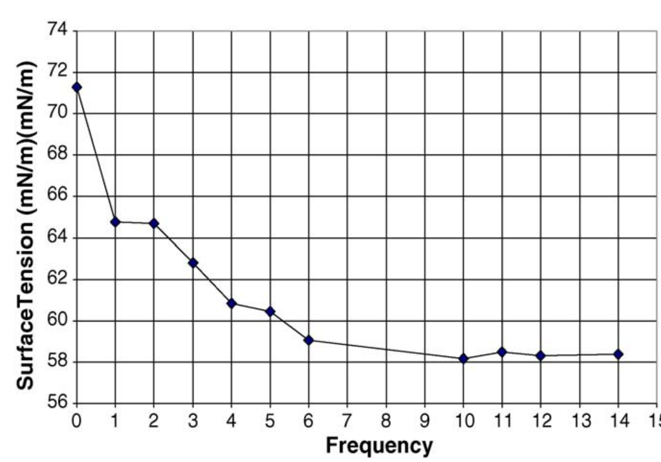

Fig. 2. Effect of the number of passes through magnetic field (frequency) on the surface tension of pure water.

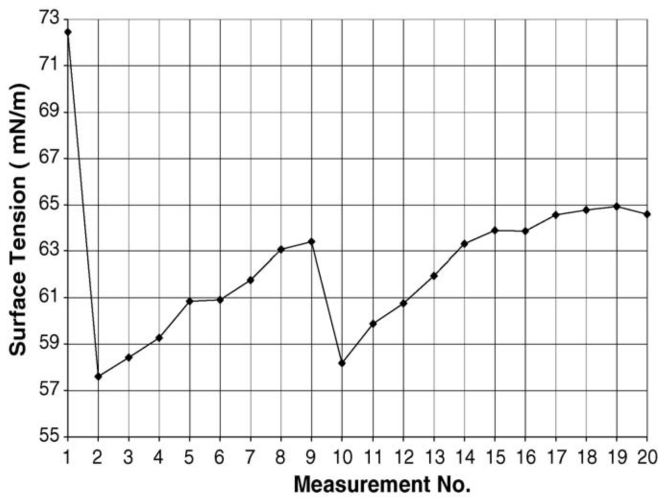

Fig. 3. Surface tension of magnetic treated pure water in various tests. Measurement no. 1 was done on pure water without MF treatment.

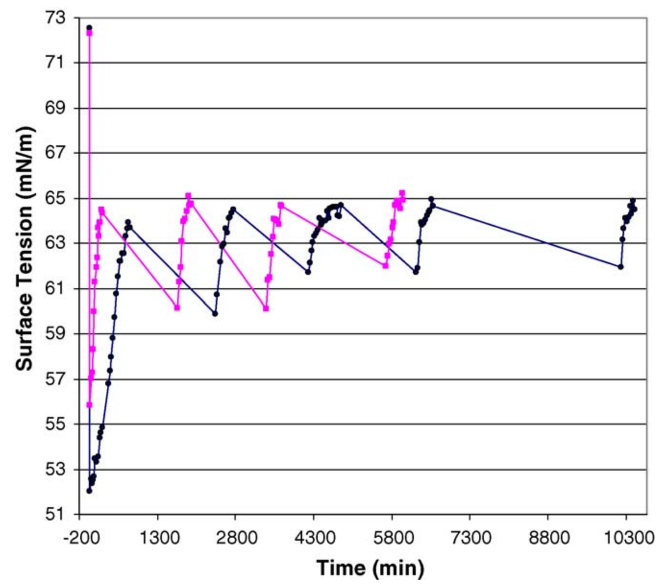

Fig. 4. Effect of time on surface tension of pure water. Upper curve: sample was circulated ten times in presence of magnetic field. Lower curve: sample was circulated ten times without MF but using a new pipe.

It was very interesting once it was observed that surface tension of treated water was not constant with time. This phenomenon was observed for treated tap and also pure water. Fig. 3 shows change in surface tension of magnetic treated pure water in various tests. The original sample was pure water with surface tension of 72.44 mN/m. The MF treatment of this sample resulted in reduction of surface tension to 57.62 mN/m (second point in Fig. 3). The treated water sample was stored at room temperature and its surface tension was measured at 1 h intervals. It was found that the surface tension of the sample gradually increased and finally it reached to 63.4 mN/m (9th point in Fig. 3). Surface tension of the same sample sharply decreased to 58.19 mN/m (10th point in Fig. 3) when it was measured on next day. However, further measurements on the same day showed that the surface tension of sample gradually increased again. This decay in surface tension was observed for more than ten samples and each time the accuracy of measurement double checked. No one has yet reported these changes in surface tension of treated water with time. It was decided to check whether the surface tension of pure water is a function of time.

Surface tension of pure water was measured in various times from a fraction of an hour (20 min) up to few days. The values were between 72 and 72.6 mN/m with an average value of 72.4 mN/m for 20 measurements. The surface tension of ordinary water at 20 °C that was released by international association for the properties of water and steam (IAPWS) is 72.74 mN/m with uncertainty of 0.36 mN/m. Therefore, there is no meaningful change in surface tension of pure water with time, i.e., surface tension of pure water is independent of time.

Therefore, decay in surface tension of MF treated pure water, as Fig. 3 shows, is important and meaningful.

4. Discussion

Surface tension results encouraged us to investigate whether or not impurities have any role in reduction of surface tension of MF treated water sample. Therefore, a comprehensive investigation was done on all components involved in water treatment circuit. The possible factor was searched by checking surface tension of passed water in each stage. It was finally probed that the main factor for changes in surface tension could be due to minute solubility of plastic materials of TYGON® pipe. Based on this finding, two samples of pure water were prepared and labeled as untreated and treated.

For eliminating any effect of the so called water memory on untreated sample, new similar TYGON® pipe was used and the vessel sample for surface tension measurement was washed with acetone and rinsed completely with pure water. Therefore, the untreated sample has only two differences with treated sample. Untreated sample was prepared using new TYGON® pipe and also without using magnetic conditioner.

Fig. 4 shows the effect of time on surface tension of magnetic treated and untreated pure waters. The original sample for upper curve was a pure water with surface tension of 72.32 mN/m. It was treated ten times according to the method shown in Fig. 1. Surface tension of this sample reduced to 58.3 mN/m. The other sample (lower curve) was pure water with surface tension of 72.54 mN/m. This sample was circulated ten times without MF but using new TYGON® pipe and its surface tension decreased to 52.03 mN/m. Each water sample was stored at room temperature and its surface tension was measured at various time intervals ranging from a fraction of an hour (20 min) up to few days. Sharp changes in each curve correspond to long time elapsed before new measurements. It is seen that the behavior of each sample is alike and can be interpreted as follows. The main factor for reduction of sample surface tension should be due to impurities, which were introduced during passing water through plastic pipe. It seems that both soluble and insoluble materials diffused in sample waters. Insoluble materials were dispersed in bulk of water. Two factors controlled the concentration of insoluble materials in each measurement, i.e., diffusion rate of insoluble materials to the surface of sample and also depletion rate of these materials because of their adsorption on surface of Du Nouy ring. Performing each new measurement results in decreasing the concentration of dispersed materials and consequently surface tension of next sample will increase.

As the diffusion coefficient of these materials seems to be low it takes a considerable time for them to reach the surface to cause reduction in surface tension of sample. For this reason, consecutive measurements usually showed a little increase in surface tension but measurement done after a long time showed a sharp reduction in the surface tension of the sample. For example, as it can be seen in the upper curve (treated sample), the measured surface tension in test no. 14 decreased from 64.35 to 60.15 mN/m on the next day or the surface tension in test no. 24 decreased from 64.76 to 60.12 mN/m on the next day (test no. 25). Similar changes occurred for the lower curve (Untreated sample), as the surface tension measured in test no. 27 decreased from 63.69 to 59.87 on the next day (test no. 28) or the surface tension in test no. 38 decreased from 64.49 to 61.71 mN/m on the other day (test no. 39).

It appears that the soluble materials were also surface active agents and they decreased the surface tension of the pure water up to 65 mN/m. It should be expected that the effect of insoluble materials finally diminish and only soluble materials have role in surface tension reduction. Fig. 4 confirms this expectation as it can be seen both curves approached to 65 mN/m even after 47 and 82 tests for treated and untreated samples, respectively.

5. Conclusions

In this work it was found that changes in surface tension of water with time can be a key point in tracing impurities in water. Meaningful changes in surface tension of a liquid sample after a day can be a good indicator for presence of physical or chemical changes in the sample.

Although relating the dye flow visualization to the changes in the surface tension of the water is possible [11], this technique should not be used for evaluating the effect of magnetic field on water because surface tension is highly sensitive to experimental conditions.

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