

The role of zinc in magnetic and other physical water treatment methods for the prevention of scale

PP Coetzee*, M Yacoby and S Howell

Department of Chemistry and Biochemistry, Rand Afrikaans University, PO Box 524, Johannesburg 2006, South Africa

Abstract

Zinc species released from the surface of physical water treatment devices into the feed water are shown to be primarily responsible for scale inhibition effects observed in three different types of physical water treatment (PWT) devices. The three types of PWT devices included units based on a magnetic field provided by a permanent magnet; a high frequency electric field; and a "catalytic conversion" process. Freshly released zinc from PWT devices was shown to have a marked effect on the induction period for CaCO_3 precipitation and on the crystal morphology of CaCO_3 . No measurable effect on the crystallisation reaction for calcium carbonate ascribable to the magnetic or electrical fields caused by the devices under investigation could be found.

Introduction

Physical water treatment (PWT) for the prevention of scale has been actively promoted as an alternative for the chemical treatment of water since the first PWT patent was registered in 1945 (Vermeiren, 1958). This patent was for magnetic water treatment. Other PWT techniques include methods based on electric or electrostatic fields, "catalytic conversion" and ultrasonic vibration. Despite numerous laboratory and field studies (Busch et al., 1986; Caplan and Stegmayer, 1987; Eliassen and Uhlig, 1952; Ellingsen and Fjedsend, 1982; Kochmarsky et al., 1982; Pandoifoet al., 1987) to prove the effectiveness of these methods, no conclusive evidence can be presented to date. Many theories have been proposed but none is able to provide a satisfactory foundation for a mechanistic explanation of the claimed effects.

It is claimed in reviews (Baker and Judd, 1996; Van der Hoven et al., 1991) that PWT leads to:

- a decreased rate of scale formation on heat exchanger surfaces
- the formation of a soft scale with a different morphology and crystal structure characterised by weaker adhesive properties
- descaling i.e. dissolution of existing scale
- increased wetting capacity
- lowering of surface tension and viscosity of water and changes in the infrared spectrum of water
- degassing of solutions
- increased capacity of ion exchangers
- increased efficiency of flotation
- a memory effect which can last up to 72 h
- the formation of smaller crystallisation particles
- increases in solubility of slightly soluble compounds
- a decrease in zeta potentials
- inhibition of bacterial and algal growth
- an increase in crop yields
- intensification of coagulation processes
- reduction in corrosion
- various other related effects.

It was our objective to find a common denominator which would link the above-mentioned diverse effects and would make possible a plausible mechanistic explanation. We assumed that scale formation proceeds through the processes of nucleation and crystal growth on exposed surfaces or in the bulk of the liquid phase followed by the attachment of crystalline particles to a surface, forming a layer prone to further growth. If PWT was to affect scale formation at all, the effect would therefore be expected to result from a modification of the crystallisation behaviour. This might be achieved by influencing nucleation and crystal growth processes directly or indirectly by changing the physico-chemical properties of the system. The latter option was included as a possibility because of claims that changes in surface tension, viscosity, and the infrared spectrum of water were observed.

Since the CaCO_3 precipitation reaction is known to be extremely sensitive to impurity ions, even at ultra-trace concentration levels, the possible release of metal ions from the surface of the PWT devices and its consequences were also investigated. This idea resulted in a breakthrough in which it was established that Zn^{2+} ions released from the device surface, were actually responsible for the observed effects of crystal morphology changes and reduced nucleation rates. These effects could translate into reduced scale formation.

Three functional types of PWT device were investigated: magnetic, high frequency electric field and catalytic conversion.

Experimental

Physical water treatment devices

Type: Permanent magnet

The Polar Model PD15 illustrated in Fig. 1 was obtained from Polar International, Sandefjord, Norway. It consisted of a steel cup which housed a well-type magnet. The size of the magnetic gaps on two sides was only 15 mm across which enabled concentration of the magnetic field in the active region to a value of 0.7 tesla. The unit was also provided with a stainless steel strainer fitted with a central rod which acted as a collector for magnetic particles that might be present in the water to be treated. This prevented the accumulation of magnetic particles in the magnet and clogging of the magnetic gaps. A 15 mm zinc sleeve

* To whom all correspondence should be addressed.

•(011) 489-2363; fax (011) 489-2363; e-mail ppc@rau3.rau.ac.za

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