Pergamon

0043-1354(95)00184-0

Wat. Res. Vol. 30, No. 2, pp. 247–260, 1996
Elsevier Science Ltd. Printed in Great Britain

REVIEW PAPER

MAGNETIC AMELIORATION OF SCALE FORMATION

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(First received January 1995; accepted in revised form August 1995)

Abstract—Process industry remains sceptical of antiscale magnetic treatment (AMT) despite its long history. Manufacturer's claims concerning AMT comprise: (a) a reduction in the amount of scale formed, (b) production of a less tenacious scale due to a change in its crystal morphology, (c) removal of existing scale, and (d) a retention of the antiscaling properties of the treated water for hours following treatment. Scientific research has both substantiated and refuted these claims, creating widespread controversy as to the credibility of this type of water conditioning. Positive results indicate effects on: (a) colloidal systems where aggregation is generally enhanced and (b) crystallisation where larger hydrophilic crystals, usually with modified crystal growth, are generated. Investigations have incorporated scaling kinetics, scale morphology, scale solubility, particle coagulation and corrosion. Effects have been reported for different scale-forming compounds and for various microscopic and macroscopic parameters in single-phase systems. AMT appears to be enhanced by prolonged or repeated magnetic exposure, and is more effective above a threshold magnetic field contact time and in flowing systems. Effects have been reported in treated waters up to 130 h after exposure has ceased. Industrial case studies indicate that the most successful implementations are in hot recirculating systems. Mechanisms presented to account for the observed effects comprise (a) intramolecular/intraionic interaction, (b) Lorentz force effects, (c) dissolution of contaminants, and (d) interfacial effects. The most plausible of these is the latter, in which the interaction of the magnetic field with the charged species present (ion clusters and crystallites) affects crystal nucleation and subsequent growth. The reported scale inhibition (and descaling) then occurs as a result of magnetically-produced hydrophilic discrete scale particles of substantially different size and crystal morphology to untreated systems, in which more adherent crystals are generated.

Key words—magnetic treatment, scale, calcium carbonate, crystallisation

1. INTRODUCTION

The build up of scale deposits is a common and costly problem in many industrial processes using natural water supplies. In Britain alone the formation of scales in industrial process plant where water is heated or used as a coolant is estimated to cost £1 billion per year (Darvill, 1993). Such costs can be attributed to cleaning (i.e. descaling) or the poor thermal conductivity of scaled surfaces; heat transfer is decreased by 95% by a $CaCO_3$ scale layer 25 mm thick (Glater *et al.*, 1980) whereas an SiO_2 scale layer 0.5 mm thick results in a 90% decrease in heat transfer (Grutsch and McClintock, 1984).

Scale formation is the precipitation of sparingly soluble salts, most commonly calcium carbonate, which form an encrustation on susceptible surfaces. Most commonly this occurs as a result of temperature or pH changes, influencing the solubility of the scale former. Other common scale-forming compounds include calcium sulphate, barium sulphate, calcium phosphate, magnesium hydroxide, zinc phosphate, iron hydroxides and silica, all of which occur naturally in raw water supplies.

Traditional chemical methods of scale control or water softening involve either the pre-precipitation of the scale former with lime or soda ash, the addition of scale inhibiting reagents or the replacement of the scale former with soluble ions by ion exchange. All of these methods, though effective in scale control, substantially change the solution chemistry and can be prohibitively expensive.

Antiscale magnetic treatment (AMT) has a long and controversial history (Eliassen *et al.*, 1958) and has been reported as being effective in numerous instances (Duffy, 1977; Donaldson and Grimes, 1988). Its effect is to either reduce scale deposition, remove existing scale or produce a softer and less tenacious scale. Many authors report large savings in energy, cleaning (i.e. descaling) and process down-time costs (Donaldson and Grimes, 1988; Anon., 1990) from the installation of magnetic water conditioners in real systems. However, installed MTD's have also often proved ineffective in real installations

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