Trendalert

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Anti-scaling magnetic treatment

Summary

Scaling in drinking water is being prevented by applying magnetism. A universally agreed mechanism, behind magnetism, is not yet available. Anti-scaling magnetism has been shown to be effective by real practice. In particular, recirculated flows with prolonged exposure, enhanced saturated conditions (i.e. higher temperatures, higher hardness and electrolyte concentrations) and coagulation and crystallization particles in the solution, are associated to successful applications. Commercial devices for scaling removal through magnetism are available. However, there are installations where magnetism does not work. Basic design for magnetic installations and operating conditions cannot be derived from fundamental knowledge. Since the characteristics of successful magnetic applications are not commonly obtained at the drinking water tap it is not likely that drinking water anti-scaling treatment will be overall effective. At full-scale water treatment plants no examples of anti-scaling magnetic installations were found. However, magnetism is being applied at full-scale water treatment plants to support removal of specific contaminants. Further applied research should either focus on water streams with super-saturated conditions, or research magnetism in combination with separation processes and nanomaterials.

Consequences

	Low	Average	High	Comments
Impact				
Certainty				

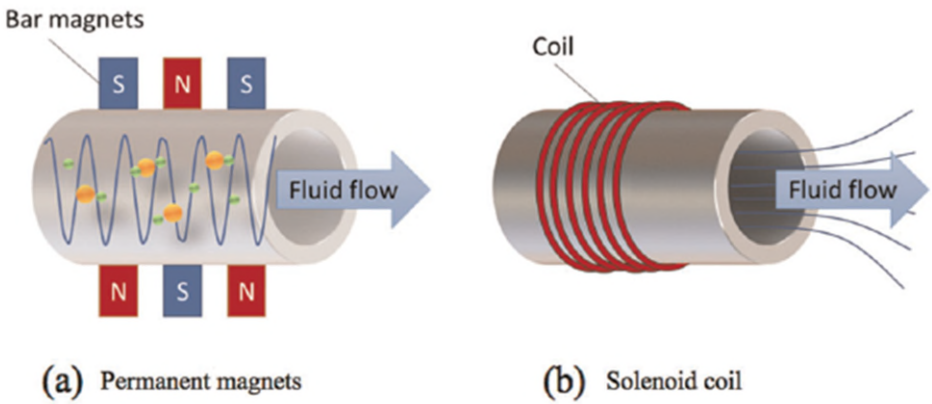

Figure 1- Typical Electromagnetic Fields (EMF) used in water systems generated by a) permanent magnets and b) solenoid coil. Source: Lin et al. (2020)

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Background

Scaling is the precipitation of sparingly soluble salts, most commonly calcium carbonate, forming an encrustation on susceptible surfaces. Carbonate precipitation, particularly in water systems with exchange heaters, is a very common problem. Magnetism can be generated by placing single or arrays of permanent magnets. When the magnetic forces are generated by electric fields, the term electromagnetism is applied (Figure 1). Anti-scale magnetic treatment (AMT) refers to all anti-scale treatments applying magnetic and electromagnetic fields (EMF). Magnetic treatment devices (MTD's) are available in intrusive and non-intrusive configurations. Intrusive devices are in direct contact with the water, and therefore have to comply with applicable legislation. Non-intrusive devices are not in contact with water. Presently, there is a tendency to apply non-intrusive devices, where is a treatment pipe associated to a compartment that produces electric pulses (Piyadasa et al. 2017).

The application of AMT in water treatment has a long controversial history (Eliassen et al. 1958). AMT has been applied in full-scale industrial installations, and while some report large savings in energy, descaling and process down-time, others report them as ineffective (Baker et al. 1996). Commercial magnetic conditioners have been shown to be effective for domestic water heaters, boilers, heat exchangers, steal humidifiers, air conditioner condensers, sugar processing plants, steam generators and cooling towers (multiple references referred by Baker et al. (1996)). MTD's also seems to effectively support removal of iron oxide scaling of thermal power plants (Nakanishi et al. 2017). Purpose built MTD's were successful employed in oilfield production applications, where the solubility of the crude oil is increased while scale and hydrocarbon build up is reduced (Corney, 1991 referred by Baker et al. (1996)). The industrial evidence contrasts with multiple impartial scientific studies results, where reproducibility of results is not consistently achieved (Baker et al. 1996, Martinez Moya et al. 2021). At full-scale water treatment plants no application of AMTs was found. Magnetic nano-composites are being applied, by the ion-exchange MIEX® technology in Australian and US water treatment plants, for removal of specific contaminants.

There is no universally agreed mechanism explaining AMT. However, scientists agree that magnetism has an anti-scaling effect that cannot be justified through factors such as water composition and specific contamination (Baker et al. 1996, Martinez Moya et al. 2021). Theories explaining magnetism through Lorentz forces, changes in ions hydrations and nucleation mechanisms have been proposed, discussed and sometimes proven by experimental results (Chibowski et al, 2018). Furthermore, MTD's change the specific heat, evaporation and boiling point characteristics of the water, enabling applications for colling and power generation (Wang et al. 2018). Overall, successful magnetic installations are associated to: orthogonal fluid flow, regarding magnetic field orientation; recirculated solution with prolonged magnetic exposure; enhanced supersaturation conditions (i.e. higher temperatures, higher hardness and electrolyte concentrations); coagulation and crystallization particles (most particles) presence in the solution (Baker et al. 1996). In the last 20 years, research on mechanisms of anti-scaling magnetism gained a new impulse, due to the possibility of applying non-invasive devices and not generating waste (Martinez Moya et al. 2021). Magnetism is currently used in water purification processes, such as, seeding and separation of magnetic flocculants, magnetic absorbents and nanomaterials (Ambashta et al. 2010).

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Relevance

Scaling, as formation of scale deposits, causes technical problems and economic loss by blocking the flow of water in pipes and decreasing thermal transfer in heat exchangers (Lin et al. 2020). The cost of scaling per household was estimated as 20 to 15 €/year (Van der Bruggen et al. (2009), Hofman et al. (2006)). The classic techniques for elimination and reduction of calcium carbonate scaling are efficient, however they can modify the composition of the water or generate a waste stream (Martinez Moya et al. 2021).

Advantages

AMT, particularly when applied as non-intrusive, does not interfere with the water composition. Moreover AMT does not produce a waste stream. Furthermore, AMT seems to favor the crystallization of aragonite instead of calcite (Chibowski et al. 2018, Martinez Moya et al. 2021), being the former easier to remove than the latter. Additionally, AMT seems to favor a bulk crystallization (Lin et al. 2020). A bulk crystallization, as opposed to surface crystallization, is when the crystals seeds form in the bulk.

Disadvantages

The efficiency of AMT is not overall assured. There is no universally agreed anti-scaling magnetic mechanism, therefore operational conditions such as field strength, field orientation, treatment time and fluid flow velocity cannot be derived from fundamental knowledge (Baker et al. 1996). Practice shows that magnetism is most effective in recirculated solution with prolonged magnetic exposure and in enhanced supersaturation conditions (higher temperatures, higher hardness, etc.). These are not the usual conditions of drinking water at the tap or at large drinking water treatment plants. Therefore, it's likely that drinking water magnetic anti-scaling techniques will not be overall effective. Anti-scaling magnetic techniques are usually considered more environmentally friendly, however the origin of magnetic particles, their manufacturing process or regeneration requirements might not have been taken into account (Martinez Moya et al. 2021).

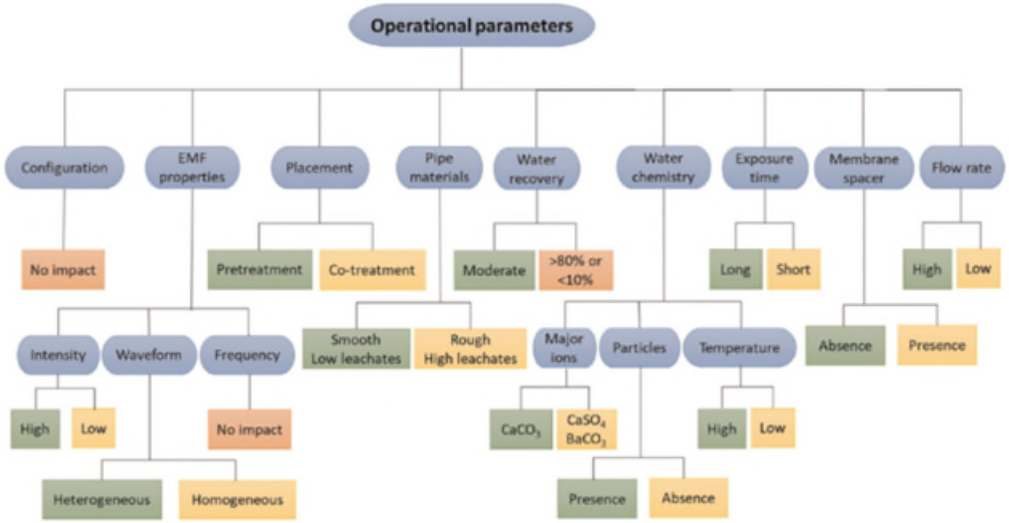

Figure 2- Impact of operational parameters on Electromagnetic Fields (EMF) treatment efficiency: Green boxes- positive; Yellow boxes- unclear; beige boxes- negative or no effect. Source: Lin et al. (2020)

Open research questions

What are the first principles behind magnetism/electromagnetism?
Why is aragonite being formed instead of calcite? Why is crystallization during magnetic treatment occurring in the bulk?
How long do the magnetic effects last?
Where and how should anti-scaling magnetism be applied?
How to apply magnetism in full-scale water treatment?

Availability

Magnetic and electromagnetic techniques to prevent scaling are being commercialized. In the Netherlands there are, at least, two known suppliers. Worldwide, most manufacturers of commercial EMF units seem to be in North America, Canada, Mexico and the UK (Piyadasa et al. 2017). MTD's are available in various configurations from various manufacturers, with some using electromagnets, and others single or arrays of permanent magnets (Baker et al. 1996). Presently, within the several commercial available EMF units for flowing water systems, there is a tendency to apply non-intrusive devices (Piyadasa et al. 2017).

More information

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Keywords

Magnetism; Electromagnetism; Electromagnetic Fields; Anti-scaling