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Technologies for the Removal of Water Hardness and Scaling Prevention

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Abstract

In nucleation assisted crystallization process formed CO_2 leaves as colloid gas and is used as the template by the rapidly growing crystals in the nucleation site. This emulsion of $CaCO_3$ micro-crystals & CO_2 micro-bubbles forms hollow particles. Formed hollow particles are double walled, both internal and external faces belonging to the cleavage aragonites which separate the surrounding water from the enclosed gas cavity. Hence, the reverse reaction of CO_2 with water forming Carbonic Acid is not possible and the pH stability is maintained. In fact every excess $CaCO_3$ crystals are buffering any carbonic acid left over. This CO_2 based nucleation technology prevents scale formation in water channels, but it also helps to reduce the previously formed scales. This process takes out water dissolved CO_2 in almost-visible micro-bubbles forms that helps reducing previously formed scale over a period of time (depends on the usage period). The aragonite crystals can't form scale because of its stable molecular structure and neutral surface electro potentiality.

Key words : water hardness, scaling formation, removal, technologies, carbonation process.

1. Introduction

Water hardness is a global environmental issue. It causes severe health problems and complex issues to industries. Large quantities of water used in various industrial categories such as food, paper, leather and thermal power plants etc. When water passes through or over mineral deposits such as limestone/dolomite, the levels of Ca^{2+}, Mg^{2+}, and HCO_3 ions present in the water greatly increase and cause the water to be classified as hard water. Here the brief mechanism of scale formation in various regions (Fig.1).

Scale formation was occurred at boilers and other taps was presented in the Fig.2.

Due to the water hardness, currently, there are several technologies and commercial softeners were available for the removal of scaling on boilers and taps. The anti-scale preventing technologies commonly used hardness removal technologies[1-3] in a residential setting are Ion Exchange (IE), Reverse Osmosis (RO), and Magnetic Water Treatment[4-7] (Fig.3).

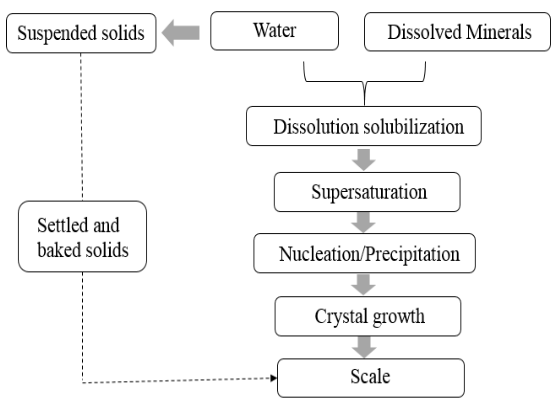

Fig. 1. The brief mechanism of scale formation.

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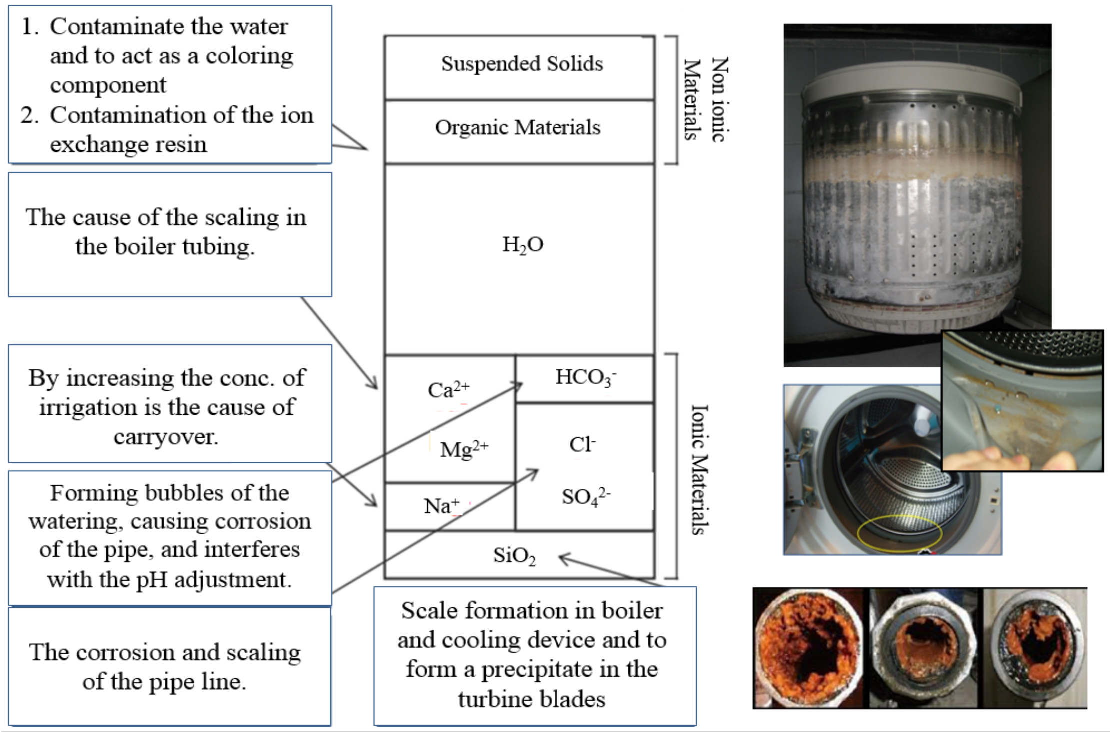

Fig. 2. Scale formation at boilers and taps.

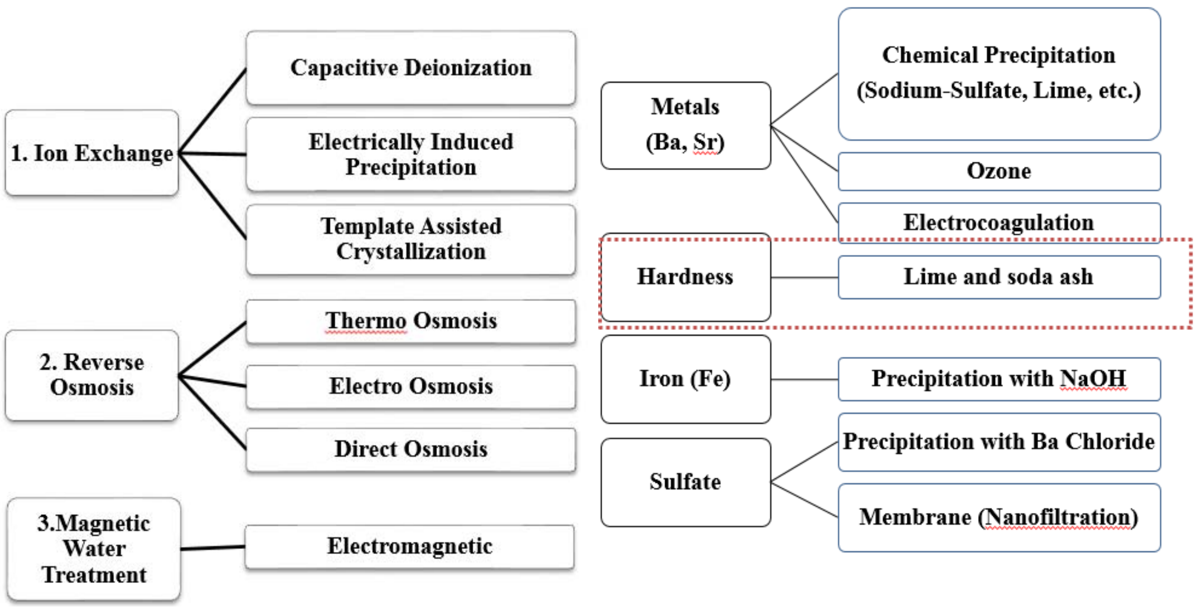

Fig. 3. Various anti scale formation technologies.

2. Global trend of anti scale treatment technologies

・Both developed countires and devloping countries suffered with water hardness and they developed various commercial softeners and treatment methodologies. Here we are presenting the various technologies which are used in different

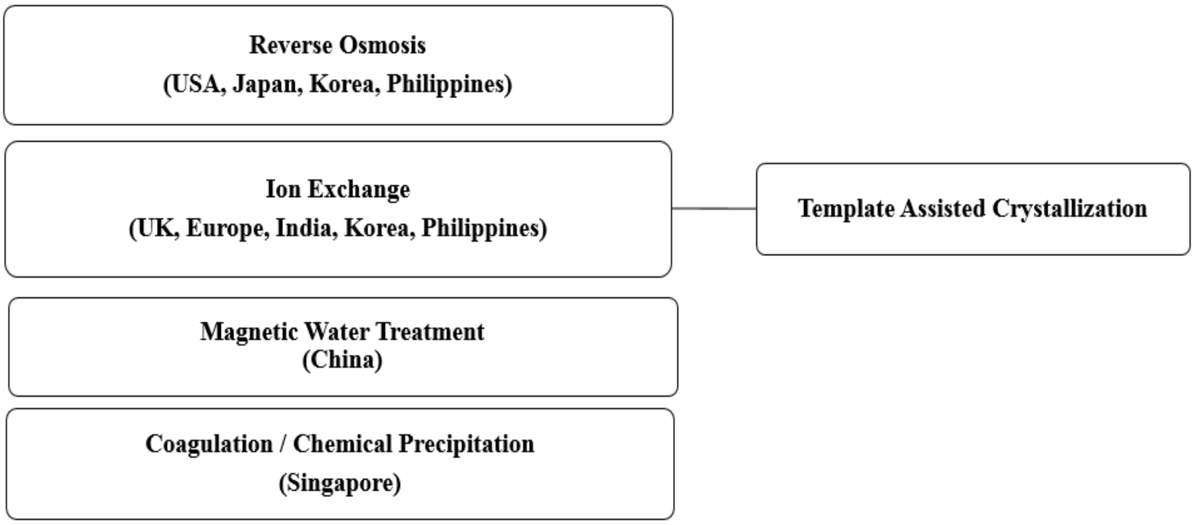

Fig. 4. Global trend of Technologies for scale prevention.

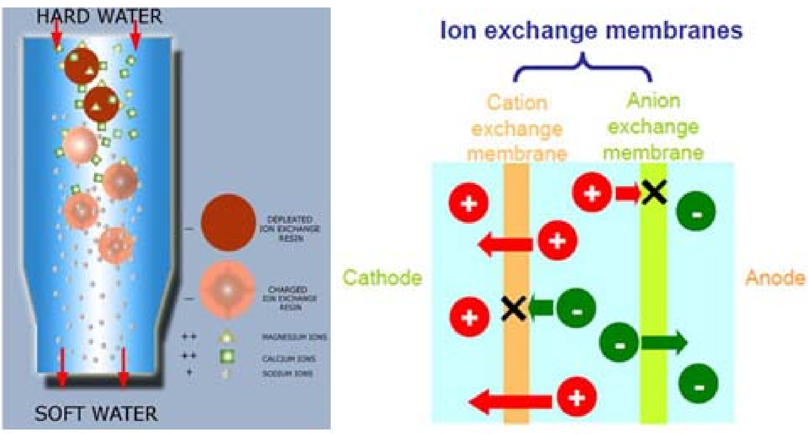

Fig. 5. Ion exchange membrane.

countries (Fig.4).

- **Reverse Osmosis** separates most effectively the feed water from its solutes.
- **Ion exchange** is a method widely used in household (laundry detergents and water filters) to produce soft water.
- **Magnetic Water Treatment** is method of reducing the effects of hard water by passing it through a magnetic field, as alternative to water softening.
- **Coagulation** (or **Chemical precipitation)** is the creation of a gel (or solid) by a chemical reaction in solution or diffusion in a solid.

2.1 Ion Exchange

Replacement of calcium ions in water with sodium ions. Target is water softeners for Drinking Water in Europe and the U.S. (Fig.5).

Ion exchange membranes[8-9] have ionic perm selectivity and are classified into cation exchange membranes and anion exchange membranes. The ion exchange resin is in the granular form and performs as adsorptive exchange of ions. Ion-Exchange, most conventional water-softening devices in which "hardness" ions trade places with sodium and chloride ions that are loosely bound to anion-exchange resin or a Zeolite (many zeolite minerals occur in

Table 1. Benefits and disadvantages of reverse osmosis technologies.

Advantages	Disadvantages
The main health advantage R.O. water has over tap water is that an R.O. system removes some unhealthy contaminants.	The water is demineralized. Drinking demineralized water associated with health risks (Removing the naturally occurring minerals also leaves the water tasteless)
A good R.O. system can remove contaminants such as arsenic, nitrates, sodium, copper and lead, some organic chemicals, and the municipal additive fluoride.	The water is usually acidic. removing the minerals makes the water acidic (often well below 7.0 pH)
Installation cost is low, it can remove total dissolved solids(TDS) and minimum usage of chemicals	Water needs extensive pre-treatment, some critical contaminants and does NOT remove volatile organic chemical (VOCs), chlorine and chloramines, pharmaceuticals

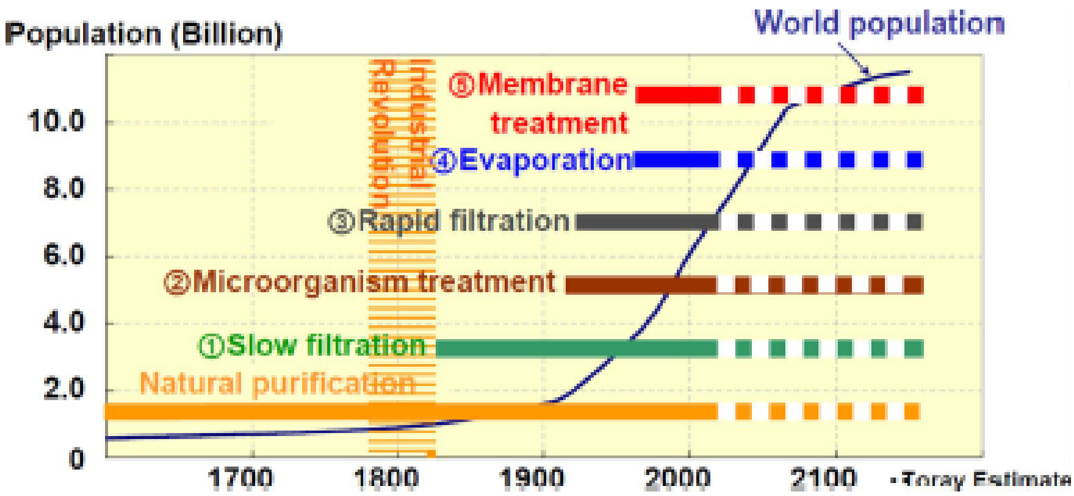

Fig. 6. Water treatment technologies

nature, but specialized ones are often made artificially.)

2.2 Reverse Osmosis

Difficult to secure volume and quality of water only by natural purification due to the increase of rapid increase of population. • Membrane Treatment Technology, which enable control of high precise water quality and high speed treatment, is essential in 21 century(Fig.6).

Adding solute to the right side increases osmotic pressure, causing water to move to the right side of the tube. Reverse osmosis (RO) is a water justification technology that uses a semipermeable membrane to remove larger particles from drinking water.

Membrane processes are especially useful where a wide range of possible contaminants have to be removed over the macro particles to ionic species. Every technology has advantages and some disadvantages and it is presented in the Table 1.

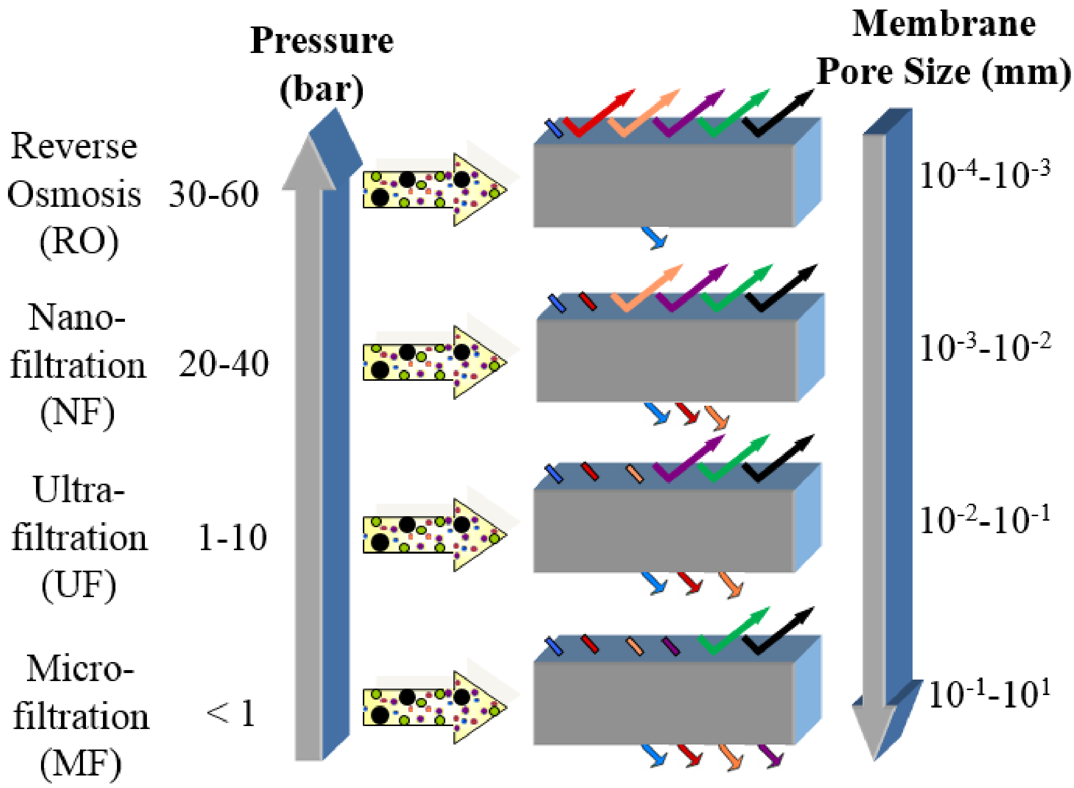

Fig. 7. Coventional Reverse Osmosis wide range possible cotaminants removal

2.3 Conventional Reverse Osmosis Membrane (CROM)

Membrane Processes are becoming popular because they are considered “Green” technology - no chemicals are used in the process. The reverse osmosis membrane is semi-permeable with thin layer of annealed material supported on a more porous sub-structure. Conventional osmosis is a water justification technology that uses a semipermeable membrane to remove larger particles from drinking water. Membrane processes are specially useful where a wide range of possible contaminants have to be removed over the macro particles to ionic species(Fig.7).

2.4 Template Assisted Crystallization (TAC) Technology

We studied the template assisted crystallization technology and it is very significant to remove the water hardness. Template assisted crystallization uses no salt or water. Its relatively new technology proven as effective in scale prevention as ion exchange and cost effective. Aragonite transforms calcium ions into calcium crystals, which are stable and cannot attach to pipes, surfaces, hardware, or heat exchangers components. The firs effective most effective zero- is charge chemical free scale prevention method. High efficiency TAC technology accelerates crystal nucleation, growth and release dramatically improving performance.

TAC promotes the formation sub-micron sized seed crystals. These newly formed crystals break away from the media surface after reaching a certain size and are carried off by the flowing water as largely colloid particles that continue to be suspended in the water. The seed crystals travel with the flowing water fulfilling the same function as the media by providing template for additional crystal formation and growth. As the dissolved calcium is removed from solution the scale potential of the water is reduced [10]. The TAC media releases a template into the water. The template attracts and captures the scale contaminants (ca, Mg and $MgCO_3$) by turning them into crystals that stick to the templates surface. The template carries the scale harmlessly throu-

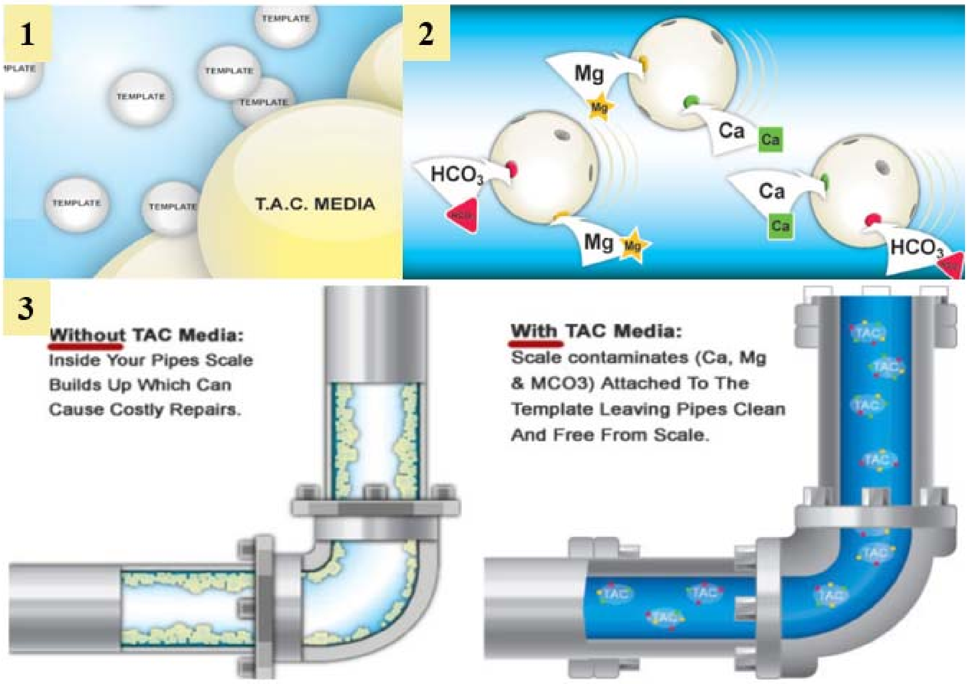

Fig. 8. TAC technologies

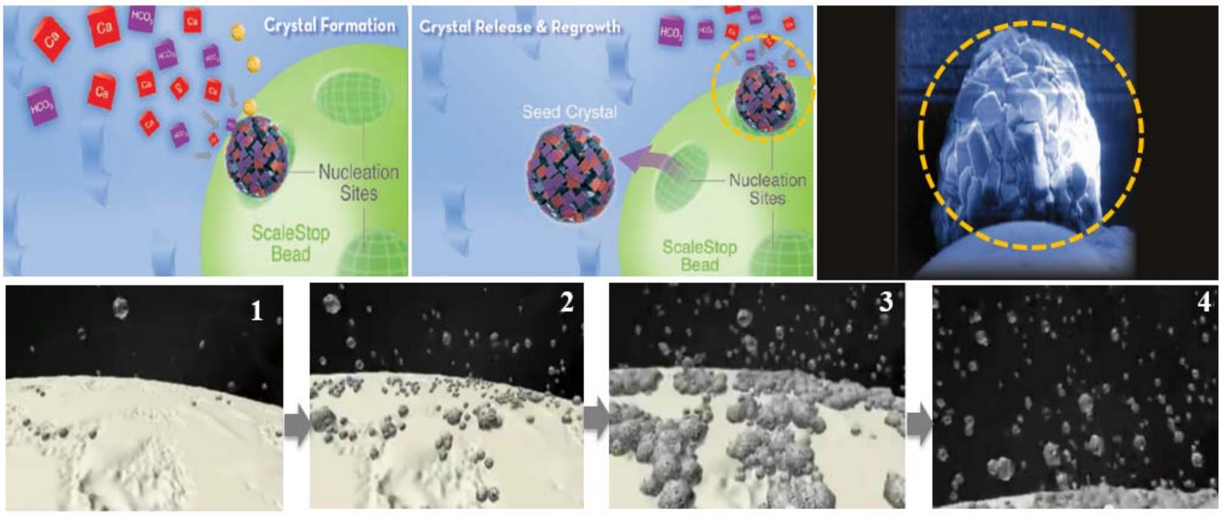

Fig. 9. Mechanism of TAC technologies; 1) TAC media media begins to attract reactive hardness ions, 2) Hardness forms nano-crystals on the media's surface, 3) Nano-crystals grow to a certain size, and 4) Once large enough, the crystals release from the bead as de-activated nano-crystals.

gh the piping. This results shows the dramatic reduction of hard water scale in pipes, appliances, heating elements, in valves and fixtures (Fig.8). The mechanism of the TAC technologies showed in the Figure (Fig.9)

2.5 TAC Mechanism

In the template assisted crystallization (TAC), four steps are involved for the final seed crystal formation. Nucleation, crystal growth, super saturation and crystallization leads the formation of crystal growth in the water. In the nucleation, the solute molecules dispersed in the solvent start to gather to create clusters, in the second step crystal growth, subsequent growth of those nuclei, the third step super saturation, nucleation and growth rate is driven by the exisitng super saturation and the final step is crystallization, in this the crystals relased from the template or beads (Fig.9)[11].

3. Conclusion

Hard water is made up of calcium ions (Ca^{2+}), magnesium ions (Mg^{2+}), and bicarbonate ions (HCO^{3-}). Aragonite transforms calcium ions into calcium crystals, which are stable and cannot attach to pipes, surfaces, hardware, or heat exchangers components. They are easily rinsed away by the water flow because the crystals are so small. Aragonite is a finer particle which is non-adherent to the inner walls of plumbing and fixtures. These particles form a talc-like powder which is soluble, allowing the nutrients to remain in your water in a bio-absorptive form. Transforms calcium ions into calcium crystals, which are stable and cannot attach to pipes, surfaces, hardware, or heat exchangers components. ScaleNet™ uses a template assisted crystallization, or TAC, process which transforms these dissolved ions into non-charged, neutral chemical bonds, of calcium and magnesium crystals. TAC has produced the first effective chemical-free scale prevention method.

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