treatments involve mechanical cleaning or hazardous and corrosive acid washes, such as hydrofluoric acid washes.

[0005] Scale inhibitors known in the art include, for example, U.S. Published Patent Application No. 2015/0076074, which discloses the use of a blend of homo-polymers of acrylic acid (AA) with either copolymers of AA and 2-acrylamido-2-methylpropane sulfonic acid (AMPS), or terpolymers of AA, AMPS, and t-Butylacrylamide (t-BAM) with EDTA to control silica and silicate scales in cooling and boiler water systems. U.S. Pat. No. 6,166,149 discloses a process for making a scale inhibitor comprising a hydrophilic graft polymer and polyether compound that optionally further comprises an unsaturated carboxylic acid type polymer. U.S. Pat. No. 5,378,368 discloses the use of polyether polyamino methylene phosphonates to control silica/silicate deposition that may be used alone or in combination with a polymer additive. U.S. Pat. No. 4,618,448 discloses the use of a carboxylic/sulphonic/polyalkylene oxide polymer as a scale inhibitor, while US. Pat. No. 4,933,090 discloses the use of a select phosphonate and optionally a carboxylic/sulphonic/polyalkylene oxide polymer to control silica/silicate deposition. Separately, U.S. Pat. No. 6,051,142 discloses the use of ethylene oxide-propylene oxide (EO-PO) block copolymers to control silica and silicate scales in cooling and boiler water systems. Finally U.S. Pat. No. 7,316,787 discloses the use of hydrophobically modified ethylene oxide polymers as colloidal silica scale inhibitors.

[0006] Despite the existence of multiple scale inhibitors, silica and metal silicate scaling continue to be major challenges in aqueous systems. In particular, while inhibitors are effective in inhibiting silica scale formation in pure silica brine conditions, such inhibitors lose their efficacy in the presence of multivalent cations that are found in many industrial applications. What is needed is a silica and metal silicate scale inhibitor that maintains its efficacy in the presence of brines comprising such multivalent cations.

SUMMARY

[0007] In accordance with the disclosure, there is provided a method of inhibiting silica and metal silicate scale formation via treating an aqueous system containing silica with an effective amount of a chelating agent blended with an alkylene oxide derived polymer dispersant. The chelating agent is blended with the polymer dispersant in a weight ratio range from greater than 1.0:0.5 to less than 1.0:3.0, agent to dispersant, including blends in a weight ratio

of 1:1. Preferably, the chelating agent is either EDTA or DTPA. It has been found that when the polymer dispersants are blended with EDTA or DTPA in the above weight ratio, the resulting blend exhibits a synergistic effect on the inhibition of colloidal silica or metal silicate formation in brine, including in the presence of multivalent cations.

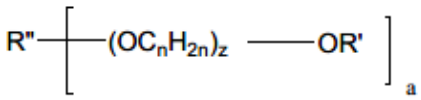
[0007a] In accordance with one aspect of the disclosure, there is provided a method of inhibiting silica and metal silicate scale formation, said method comprising the steps of:

treating an aqueous system comprising silica with an effective amount of a mixture of a chelating agent and an acid and alkylene oxide derived polymer dispersant;

wherein said chelating agent is ethylenediaminetetraacetic acid (EDTA) or diethylene triamine pentaacetic acid (DTPA);

wherein said acid and alkylene oxide derived polymer dispersant has a number average molecular weight from 500 Daltons to 40,000 Daltons and is

(1) a polymerizable-acid graft polymer comprising from 3.0% to 35% by weight of an unsaturated grafting acid and an alkylene oxide polymer backbone, said alkylene oxide polymer backbone having the following formula:



wherein each R' is independently selected from the group consisting of hydrogen, a methyl group, an ethyl group, and an amine groups;

wherein R" is independently selected from the group consisting of hydrogen, a methyl group, an ethyl group, and an amine group;

wherein each "Z" has, independently, a value of from 4 to 1,800;

wherein "a" has a value of from 1 to 4;

wherein each "n" has, independently, a value of from 2 to 4, such that said alkylene oxide polymer backbone comprises either ethylene oxide repeat units, propylene oxide repeat units, butylene oxide repeat units, or copolymers thereof; and;

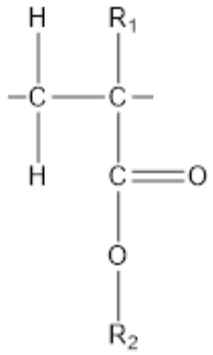
wherein said grafting acid is selected from the group consisting of acrylic acid, methacrylic acid, itaconic acid, maleic acid, 2 acrylamido-2-methylpropylsulfonic acid (AMPS), 2-methacrylamido-2-methylpropylsulfonic acid, styrene sulfonic acid, vinylsulfonic acid, ethylene glycol methacrylate phosphate, vinyl phosphonic acid and mixtures thereof;

or

(2) a bottle brush polymer comprising side chains A, backbone B, and optionally side chains C;

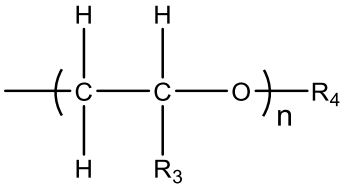
wherein A is the repeat unit obtained after the polymerization of one or more anionic monomers selected from the group consisting of carboxylic acid, carboxylate, sulfonic acid, sulfonate, acrylic phosphate, and mixtures thereof;

wherein B is the repeat unit obtained after the polymerization of one or more polyoxoalkylene-containing monomers having the chemical formula:



wherein R_1 is H or CH_3;

wherein R_2 has the chemical formula:



wherein R_3 is H, CH_3, or mixtures thereof;

wherein R_4 is H, or a C_1 through C_4 alkyl group, or mixtures thereof;

wherein n = 5-100;

wherein C is the repeat unit obtained after the polymerization of one or more nonionic monomers selected from the group consisting of methacrylates, acrylates, and acrylamides;

wherein A comprises from 5 wt.% to 45 wt.% of the bottle brush polymer;

wherein B comprises 55 wt.% to 95 wt.% of the bottle brush polymer;

wherein C comprises 0 wt.% to 25 wt.% of the bottle brush polymer;

wherein A is selected from the group consisting of acrylic acid, the salt of acrylic acid, methacrylic acid, the salt of methacrylic acid, itaconic acid, the salt of itaconic acid, maleic acid, the salt of maleic acid, 2-acrylamido-2-methylpropylsulfonic acid (AMPS), the salt of AMPS, 2-methacrylamido-2-methylpropylsulfonic acid, the salt of 2-methacrylamido-2-methylpropylsulfonic

acid, styrene sulfonic acid, the salt of styrene sulfonic acid, vinylsulfonic acid, the salt of vinylsulfonic acid, ethylene glycol methacrylate phosphate, and mixtures thereof;

wherein B is selected from the group consisting of polyoxoalkylene acrylates, methacrylates, polyethylene glycol methacrylate, polyethylene glycol acrylate, polyethylene glycol methyl ether methacrylate, polyethylene glycol methyl ether acrylate, and mixtures thereof; and

wherein C is present and is selected from the group consisting of methyl methacrylate, ethyl acrylate, hydroxy ethyl methacrylate hydroxy propyl acrylate and cellosolve acrylate, (meth)acrylamide, N-methyl acrylamide, N,N-dimethylacrylamide, N-isopropyl acrylamide, N-t-butyl acrylamide, N,N-dimethylaminoethyl (meth)acrylate, t-butyl acrylamide, t-octyl acrylamide, dimethylacrylamide, and mixtures thereof;

wherein said chelating agent is mixed with said acid and alkylene oxide derived polymer dispersant in a weight ratio from greater than 1.0:0.5 to less than 1.0:3.0, agent to dispersant.

BRIEF DESCRIPTION OF THE FIGURES

[0008] FIG. 1 is a chart depicting percent inhibition of a control and scale inhibitors Sample A through Sample G for 400 ppm silica in presence of Na^+, K^+, Ca^{2+}, Mg^{2+}, and Al^{3+}.

[0009] FIG. 2 is a chart depicting reactive silica in solution using a control and scale inhibitors Sample A through Sample G for 400 ppm silica in presence of Na^+, K^+, Ca^{2+}, Mg^{2+}, and Al^{3+}.

[0010] FIG. 3 is a chart depicting percent inhibition of a control and scale inhibitors Sample A, Sample D, and Sample H for 400 ppm silica in presence of Na^+, K^+, Ca^{2+}, Mg^{2+}, and Al^{3+}.

[0011] FIG. 4 is a chart depicting reactive silica in solution using a control and scale inhibitors Sample A, Sample D, and Sample H for 400 ppm silica in presence of Na^+, K^+, Ca^{2+}, Mg^{2+}, and Al^{3+}.

[0012] FIG. 5 is a chart depicting percent inhibition of a control and scale inhibitors Sample A, Sample D, and Sample I for 400 ppm silica in presence of Na^+, K^+, Ca^{2+}, Mg^{2+}, and Al^{3+}.

[0013] FIG. 6 is a chart depicting reactive silica in solution using a control and scale inhibitors Sample A, Sample D, and Sample I for 400 ppm silica in presence of Na^+, K^+, Ca^{2+}, Mg^{2+}, and Al^{3+}.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0014] The disclosed invention covers a method of inhibiting silica and metal silicate scale formation via treating an aqueous system containing silica with an effective amount of a chelating agent blended with an alkylene oxide derived polymer dispersant. The chelating agent is blended with the polymer dispersant in a weight ratio range from greater than 1.0:0.5 to less than 1.0:3.0, agent to dispersant, including blends in a weight ratio of 1:1. It has been found that when the polymer dispersants are blended with the chelating agent in the above weight ratios, the resulting

CLAIMS

What is claimed is:

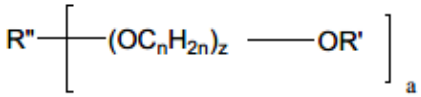
1. A method of inhibiting silica and metal silicate scale formation, said method comprising the steps of:

treating an aqueous system comprising silica with an effective amount of a mixture of a chelating agent and an acid and alkylene oxide derived polymer dispersant;

wherein said chelating agent is ethylenediaminetetraacetic acid (EDTA) or diethylene triamine pentaacetic acid (DTPA);

wherein said acid and alkylene oxide derived polymer dispersant has a number average molecular weight from 500 Daltons to 40,000 Daltons and is

(1) a polymerizable-acid graft polymer comprising from 3.0% to 35% by weight of an unsaturated grafting acid and an alkylene oxide polymer backbone, said alkylene oxide polymer backbone having the following formula:



wherein each R' is independently selected from the group consisting of hydrogen, a methyl group, an ethyl group, and an amine groups;

wherein R" is independently selected from the group consisting of hydrogen, a methyl group, an ethyl group, and an amine group;

wherein each "Z" has, independently, a value of from 4 to 1,800;

wherein "a" has a value of from 1 to 4;

wherein each "n" has, independently, a value of from 2 to 4, such that said alkylene oxide polymer backbone comprises either ethylene oxide repeat units, propylene oxide repeat units, butylene oxide repeat units, or copolymers thereof; and;

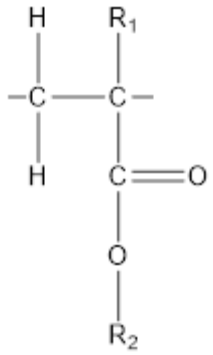
wherein said grafting acid is selected from the group consisting of acrylic acid, methacrylic acid, itaconic acid, maleic acid, 2 acrylamido-2-methylpropylsulfonic acid (AMPS), 2-methacrylamido-2-methylpropylsulfonic acid, styrene sulfonic acid, vinylsulfonic acid, ethylene glycol methacrylate phosphate, vinyl phosphonic acid and mixtures thereof;

or

(2) a bottle brush polymer comprising side chains A, backbone B, and optionally side chains C;

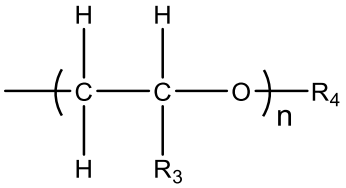
wherein A is the repeat unit obtained after the polymerization of one or more anionic monomers selected from the group consisting of carboxylic acid, carboxylate, sulfonic acid, sulfonate, acrylic phosphate, and mixtures thereof;

wherein B is the repeat unit obtained after the polymerization of one or more polyoxoalkylene-containing monomers having the chemical formula:



wherein R_1 is H or CH_3;

wherein R_2 has the chemical formula:



wherein R_3 is H, CH_3, or mixtures thereof;

wherein R_4 is H, or a C_1 through C_4 alkyl group, or mixtures thereof;

wherein n = 5-100;

wherein C is the repeat unit obtained after the polymerization of one or more nonionic monomers selected from the group consisting of methacrylates, acrylates, and acrylamides;

wherein A comprises from 5 wt.% to 45 wt.% of the bottle brush polymer;

wherein B comprises 55 wt.% to 95 wt.% of the bottle brush polymer;

wherein C comprises 0 wt.% to 25 wt.% of the bottle brush polymer;

wherein A is selected from the group consisting of acrylic acid, the salt of acrylic acid, methacrylic acid, the salt of methacrylic acid, itaconic acid, the salt of itaconic acid, maleic acid, the salt of maleic acid, 2-acrylamido-2-methylpropylsulfonic acid (AMPS), the salt

of AMPS, 2-methacrylamido-2-methylpropylsulfonic acid, the salt of 2-methacrylamido-2-methylpropylsulfonic acid, styrene sulfonic acid, the salt of styrene sulfonic acid, vinylsulfonic acid, the salt of vinylsulfonic acid, ethylene glycol methacrylate phosphate, and mixtures thereof;

wherein B is selected from the group consisting of polyoxoalkylene acrylates, methacrylates, polyethylene glycol methacrylate, polyethylene glycol acrylate, polyethylene glycol methyl ether methacrylate, polyethylene glycol methyl ether acrylate, and mixtures thereof; and

wherein C is present and is selected from the group consisting of methyl methacrylate, ethyl acrylate, hydroxy ethyl methacrylate hydroxy propyl acrylate and cellosolve acrylate, (meth)acrylamide, N-methyl acrylamide, N,N-dimethylacrylamide, N-isopropyl acrylamide, N-t-butyl acrylamide, N,N-dimethylaminoethyl (meth)acrylate, t-butyl acrylamide, t-octyl acrylamide, dimethylacrylamide, and mixtures thereof;

wherein said chelating agent is mixed with said acid and alkylene oxide derived polymer dispersant in a weight ratio from greater than 1.0:0.5 to less than 1.0:3.0, agent to dispersant.

2. The method of claim 1, wherein said alkylene oxide polymer backbone is a copolymer of ethylene oxide and propylene oxide polymers having a weight ratio from 45:55 to 55:45 ethylene oxide to propylene oxide; and

wherein 10 % of said repeat units of said alkylene oxide polymer backbone are grafted with said acrylic acid.

3. The method of claim 1, wherein A is said methacrylic acid and is from 5 wt.% to 10 wt.% of the bottle brush polymer;

wherein B is said polyethylene glycol methyl ether methacrylate and is from 70 wt.% to 75 wt.% of the bottle brush polymer; and

wherein C is said methyl methacrylate and is from 20 wt.% to 23 wt.% of the bottle brush polymer.

4. The method of claim 1, wherein A is said acrylic acid and is from 8 wt.% to 10 wt.% of the bottle brush polymer;

wherein B is said polyethylene glycol methyl ether methacrylate and is from 80 wt.% to 84 wt.% of the bottle brush polymer; and

wherein C is said methacrylic acid and is from 8 wt.% to 10 wt.% of the bottle brush polymer.

5. The method of claim 1, wherein said acid and alkylene oxide derived polymer dispersant has a number average molecular weight from 2,500 Daltons to 12,000 Daltons.