CLAIMS

What is claimed is:

1. A method for sequestering cations that can precipitate from an aqueous composition, the method comprising:

adding a multi-dentate ligand to an aqueous composition that includes (a) monovalent ions selected from Na^+, K^+, Cl^-, and combinations thereof and (b) at least one type of dissolved metal-divalent cation that can precipitate from the aqueous composition to produce scaling; then

enabling the multi-dentate ligand to bond with the dissolved metal-divalent cation to form an aqueous non-scaling ionic complex; then

filtering the aqueous non- scaling ionic complex from the aqueous composition with a membrane with sub-1-µm pores that retains the aqueous non-scaling ionic complex in a brine and that passes a remnant of the aqueous composition;

reducing the pH of the filtered brine to release the metal-divalent cation from the multi-dentate ligand; and

after the metal-divalent cation is released, reintroducing the multi-dentate ligand into additional aqueous composition to form additional non-scaling ionic complex in a predominantly closed loop.

2. The method of claim 1, wherein the dissolved metal-divalent cation includes at least one of the following: calcium, barium, strontium and magnesium.

3. The method of claim 1, wherein the aqueous composition includes flowback water or produced water from oil or gas extraction.

4. The method of claim 1, wherein the aqueous composition includes at least one of sea water and brackish water.

5. The method of claim 1, wherein the aqueous composition includes waste water.

6. The method of claim 1, wherein the pH of the filtered brine is reduced via addition of an acid to release the scaling component from the multi-dentate ligand.

7. The method of claim 1, further comprising separating purified water from the brine with the non-scaling ionic complex included in the brine.

8. The method of claim 1, further comprising separating purified water from other components of the remnant of the aqueous composition is performed in a high-recovery desalination system via a desalination process selected from at least one of the following: reverse osmosis, multi-stage flash distillation, multiple-effect distillation, mechanical vapor recompression, electrodialysis, membrane distillation, directional solvent extraction and humidification-dehumidification.

9. The method of claim 1, further comprising heating the remnant of the aqueous composition up to a temperature at which the dissolved metal-divalent cation would precipitate from the aqueous composition if the dissolved metal-divalent cation remained in the remnant of the aqueous composition in unbounded form.

10. The method of claim 9, wherein the remnant of the aqueous composition is heated up to a temperature of at least 50°C.

11. The method of claim 1, wherein the pH of the brine including the ionic complex is reduced by adding an acid to the brine, the method further comprising adding a base to the brine after the multi-dentate ligand is released and removed, wherein the base neutralizes the acid.

12. The method of claim 1, wherein the brine including the ionic complex is cooled to less than 20°C after the pH is reduced to increase the amount of multi-dentate ligand released from the metal-divalent cation.

13. The method of claim 1, wherein the multi-dentate ligand comprises an ethylenediamine tetra-acetate ion.

14. An apparatus for scaling-preventive desalination, the apparatus comprising:

a source of an aqueous composition including (a) monovalent ions selected from Na^+, K^+, Cl^-, and combinations thereof and (b) at least one type of dissolved metal-divalent cation that can precipitate from the aqueous composition to produce scaling;

a desalination system;

a first conduit configured to feed the aqueous composition from the aqueous-composition source to the desalination system;

a source of a multi-dentate ligand;

a second conduit configured to feed the multi-dentate ligand from the multi-dentate-ligand source into the first conduit to bond the multi-dentate ligand with metal-divalent cations in the aqueous composition to form a non-scaling ionic complex;

a filtration unit coupled with the first conduit and configured to receive the aqueous composition with the non-ionic scaling complex, wherein the filtration unit includes a membrane with sub-1-µm pores sized to pass a remnant of the aqueous composition before the remnant of the aqueous composition is fed to the desalination system;

a pH-reduction apparatus coupled with a source of a pH-reducing agent and configured to separate the metal-divalent cations from the multi-dentate ligand; and

a third conduit configured to feed the non-scaling ionic complex from the filtration unit to the pH-reduction apparatus.

15. The apparatus of claim 14, wherein the second conduit is configured to feed the multi-dentate ligand from the pH-reduction apparatus into the first conduit.

16. The apparatus of claim 15, wherein the ultra-filtration unit is coupled with the first conduit and configured to separate the non-scaling complex from the remnant of the aqueous composition before the aqueous composition is fed to the desalination system.