CLAIMS

What is claimed is

1. A process for purifying contaminated water comprising:

providing a contaminated feed solution stream comprising water and having a first osmotic pressure on a feed side of a semipermeable membrane;

providing a draw solution stream comprising a draw solute and having a second osmotic pressure on a draw side of the semipermeable membrane;

passing water through the semipermeable membrane to the draw side to produce a diluted draw solution stream;

heating the diluted draw solution stream to supersaturate the diluted draw solution stream;

precipitating the draw solute in the diluted dilute draw solution stream to produce a precipitated two phase effluent stream;

agglomerating the draw solute in the precipitated two phase effluent stream to produce an agglomerated effluent stream;

separating the agglomerated draw solute from the agglomerated effluent stream to produce a water rich stream comprising water and residual draw solute and a solute rich stream comprising agglomerated draw solute and water;

cooling the water rich stream to produce a cooled single phase water rich stream; and

separating the residual draw solute from the cooled single phase water rich stream to produce a residual draw solute stream and a purified water product stream.

2. The process as recited in claim 1, further comprising:

cooling the solute rich stream to produce a cooled solute rich stream comprising draw solute and water;

combining the residual draw solute stream with the cooled solute rich stream to produce a reconstituted draw solution; and

recycling the reconstituted draw solution to the draw side of the semipermeable membrane.

3. The process as recited in claim 1, wherein heating the diluted draw solution comprises heating the diluted draw solution in a heat exchanger network.

4. The process as recited in claim 1, wherein agglomerating the draw solute comprises agglomerating the draw solute in a coalescer.

5. The process as recited in claim 1, wherein separating the agglomerated draw solute from the agglomerated effluent stream comprises separating the agglomerated draw solute from the agglomerated effluent stream in a gravity phase separator.

6. The process as recited in claim 1, wherein cooling the water rich stream comprises cooling the water rich stream in the heat exchanger network.

7. The process as recited in claim 1, wherein separating the residual draw solute from the cooled single phase water rich stream comprises separating the residual draw solute from the cooled single phase water rich stream in a nanofilter, ultrafilter or a reverse osmosis module.

8. The process as recited in claim 2, wherein cooling the solute rich stream comprises cooling the solute rich stream in the heat exchanger network.

9. The process as recited in claim 4, wherein the cloud point temperature of the draw solute is between 40 °C and 90 °C and the operating temperature of the coalescer is less than 150 °C.

10. The process as recited in claim 1, wherein the concentration of the residual draw solute in the water rich stream is less than 5% by weight solute in solution.

11. The process as recited in claim 1, wherein the osmotic pressure of the single phase cooled water rich stream is less than 50 mOsm.

12. The process as recited in claim 1, wherein the concentration of solute in the solute rich stream is greater than 60% by weight solute in solution.

13. The process as recited in claim 1, wherein the draw solute is a random or sequential copolymer of low molecular weight diols.

14. The process as recited in claim 13, wherein the molecular weight of the random or sequential copolymer is greater than 500 and osmotic pressure of a 40% by weight solute in solution is greater than 30 atm.

15. The process as recited claim 13, wherein the low molecular weight diols are ethane diol and propane diol and the cloud point temperature, solubility, and osmotic pressure of the

draw solute are controlled by adjusting the ethane diol to propane diol ratio and by adjusting the molecular weight of the draw solute.

16. The process as recited in claim 1, further comprising measuring the concentration or osmotic pressure of the residual draw solute in the water rich stream and controlling the concentration or osmotic pressure of the residual draw solute by adjusting the operating temperature of the coalescer.

17. The process as recited in claim 1, further comprising controlling the flow rate of the draw solution stream to maintain a predetermined concentration of draw solute in the diluted draw solution stream.

18. The process as recited in claim 4, wherein the coalescer is segregated into a top section comprising hydrophobic coalescing elements for agglomerating the draw solute and a bottom section comprising hydrophilic coalescing elements for water aggregation, wherein the degree of hydrophobicity of the hydrophobic coalescing elements and the degree of hydrophilicity of the hydrophilic coalescing elements are selected to agglomerate the draw solute to greater than 10 μm.

19. The process as recited in claim 3, wherein the heat exchanger network comprises at least two heat exchangers.

20. The process as recited in claim 7, wherein the nanofilter, ultrafilter or reverse osmosis process comprises a molecular weight cutoff less than 2000, a NaCl rejection less than 50% and a draw solute rejection greater than 95%.

21. The process as recited in claim 1, wherein a microorganism concentration of the draw solute in the process is controlled with a UV sterilizer or a biocide.

22. The process as recited in claim 7, wherein an advanced oxidation process or adsorption system is used to remove the residual draw solute from the filter permeate of the nanofilter, ultrafilter or reverse osmosis module.

23. A system for purifying contaminated water comprising:

a semipermeable membrane comprising a feed side for receiving a contaminated feed solution stream comprising water and having a first osmotic pressure and a draw side for receiving a draw solution stream comprising a draw solute and having a second osmotic pressure, wherein the semipermeable membrane is configured to pass water from the contaminated feed solution stream to the draw side to produce a diluted draw solution stream;

a first heat exchanger configured for heating the diluted draw solution stream;

a coalescer configured for agglomerating the draw solute in the diluted draw solution stream to produce an agglomerated effluent stream;

a gravity phase separator configured for separating the agglomerated draw solute from the agglomerated effluent stream to produce a water rich stream comprising water and residual draw solute and a solute rich stream comprising agglomerated draw solute and water;

a second heat exchanger configured for cooling the water rich stream to produce a cooled single phase water rich stream; and

a reverse osmosis module configured for separating the residual draw solute from the cooled single phase water rich stream to produce a residual draw solute stream and a purified water product stream.

What is claimed is

1. A process for purifying contaminated water comprising:

providing a contaminated feed solution stream comprising water and having a first osmotic pressure on a feed side of a semipermeable membrane;

providing a draw solution stream comprising a draw solute and having a second osmotic pressure on a draw side of the semipermeable membrane;

passing water through the semipermeable membrane to the draw side to produce a diluted draw solution stream;

heating the diluted draw solution stream to supersaturate the diluted draw solution stream;

precipitating the draw solute in the diluted dilute draw solution stream to produce a precipitated two phase effluent stream;

agglomerating the draw solute in the precipitated two phase effluent stream to produce an agglomerated effluent stream;

separating the agglomerated draw solute from the agglomerated effluent stream to produce a water rich stream comprising water and residual draw solute and a solute rich stream comprising agglomerated draw solute and water;

cooling the water rich stream to produce a cooled single phase water rich stream; and

separating the residual draw solute from the cooled single phase water rich stream to produce a residual draw solute stream and a purified water product stream.

2. The process as recited in claim 1, further comprising:

cooling the solute rich stream to produce a cooled solute rich stream comprising draw solute and water;

combining the residual draw solute stream with the cooled solute rich stream to produce a reconstituted draw solution; and

recycling the reconstituted draw solution to the draw side of the semipermeable membrane.

3. The process as recited in claim 1, wherein heating the diluted draw solution comprises heating the diluted draw solution in a heat exchanger network.

4. The process as recited in claim 1, wherein agglomerating the draw solute comprises agglomerating the draw solute in a coalescer.

5. The process as recited in claim 1, wherein separating the agglomerated draw solute from the agglomerated effluent stream comprises separating the agglomerated draw solute from the agglomerated effluent stream in a gravity phase separator.

6. The process as recited in claim 1, wherein cooling the water rich stream comprises cooling the water rich stream in the heat exchanger network.

7. The process as recited in claim 1, wherein separating the residual draw solute from the cooled single phase water rich stream comprises separating the residual draw solute from the cooled single phase water rich stream in a nanofilter, ultrafilter or a reverse osmosis module.

8. The process as recited in claim 2, wherein cooling the solute rich stream comprises cooling the solute rich stream in the heat exchanger network.

9. The process as recited in claim 4, wherein the cloud point temperature of the draw solute is between 40 °C and 90 °C and the operating temperature of the coalescer is less than 150 °C.

10. The process as recited in claim 1, wherein the concentration of the residual draw solute in the water rich stream is less than 5% by weight solute in solution.

11. The process as recited in claim 1, wherein the osmotic pressure of the single phase cooled water rich stream is less than 50 mOsm.

12. The process as recited in claim 1, wherein the concentration of solute in the solute rich stream is greater than 60% by weight solute in solution.

13. The process as recited in claim 1, wherein the draw solute is a random or sequential copolymer of low molecular weight diols.

14. The process as recited in claim 13, wherein the molecular weight of the random or sequential copolymer is greater than 500 and osmotic pressure of a 40% by weight solute in solution is greater than 30 atm.

15. The process as recited claim 13, wherein the low molecular weight diols are ethane diol and propane diol and the cloud point temperature, solubility, and osmotic pressure of the draw solute are controlled by adjusting the ethane diol to propane diol ratio and by adjusting the molecular weight of the draw solute.

16. The process as recited in claim 1, further comprising measuring the concentration or osmotic pressure of the residual draw solute in the water rich stream and controlling the concentration or osmotic pressure of the residual draw solute by adjusting the operating temperature of the coalescer.

17. The process as recited in claim 1, further comprising controlling the flow rate of the draw solution stream to maintain a predetermined concentration of draw solute in the diluted draw solution stream.

18. The process as recited in claim 4, wherein the coalescer is segregated into a top section comprising hydrophobic coalescing elements for agglomerating the draw solute and a bottom section comprising hydrophilic coalescing elements for water aggregation, wherein the degree of hydrophobicity of the hydrophobic coalescing elements and the degree of hydrophilicity of the hydrophilic coalescing elements are selected to agglomerate the draw solute to greater than 10 μm.

19. The process as recited in claim 3, wherein the heat exchanger network comprises at least two heat exchangers.

20. The process as recited in claim 7, wherein the nanofilter, ultrafilter or reverse osmosis process comprises a molecular weight cutoff less than 2000, a NaCl rejection less than 50% and a draw solute rejection greater than 95%.

21. The process as recited in claim 1, wherein a microorganism concentration of the draw solute in the process is controlled with a UV sterilizer or a biocide.

22. The process as recited in claim 7, wherein an advanced oxidation process or adsorption system is used to remove the residual draw solute from the filter permeate of the nanofilter, ultrafilter or reverse osmosis module.

23. A system for purifying contaminated water comprising:

a semipermeable membrane comprising a feed side for receiving a contaminated feed solution stream comprising water and having a first osmotic pressure and a draw side for receiving a draw solution stream comprising a draw solute and having a second osmotic pressure, wherein the semipermeable membrane is configured to pass water from the contaminated feed solution stream to the draw side to produce a diluted draw solution stream;

a first heat exchanger configured for heating the diluted draw solution stream;

a coalescer configured for agglomerating the draw solute in the diluted draw solution stream to produce an agglomerated effluent stream;

a gravity phase separator configured for separating the agglomerated draw solute from the agglomerated effluent stream to produce a water rich stream comprising water and residual draw solute and a solute rich stream comprising agglomerated draw solute and water;

a second heat exchanger configured for cooling the water rich stream to produce a cooled single phase water rich stream; and

a reverse osmosis module configured for separating the residual draw solute from the cooled single phase water rich stream to produce a residual draw solute stream and a purified water product stream.