CLAIMS

1. A method of purifying water comprising:

providing a feed water comprising greater than about 1,000 ppm total dissolved solids to a nanofiltration device to produce a first filtrate reduced in total dissolved solids; and

feeding the first filtrate to an electrodeionization device to produce a second filtrate comprising less than about 1,000 ppm total dissolved solids.

2. The method of claim 1, wherein the feed water is seawater, brackish water or oil field recovery water.

3. The method of claim 1, wherein greater than about 90 % of any multivalent ions are removed by the nanofiltration device.

4. The method of claim 1, wherein the nanofiltration device is operated at an upstream pressure of less than about 600 psi.

5. The method of claim 1, further comprising reducing the boron content in the feed water to less than about 0.5 ppm.

6. The method of claim 1, that consumes energy at an overall rate of less than about 7 kwh/kgal.

7. The method of claim 1, wherein the second filtrate comprises less than or equal to about 500 ppm total dissolved solids.

8. An apparatus for desalinating seawater comprising:

a nanofiltration device; and

an electrodeionization device in fluid communication with the nanofiltration device.

9. The apparatus of claim 8, further comprising a pretreatment device positioned upstream of the nanofiltration device, the pretreatment device selected from the group consisting of a bed filter, a microfilter, a crossflow microfilter, a settling tank, and an aerator.

10. The apparatus of claim 8, wherein the electrodeionization device comprises a CEDI device including dilution cells having a thickness of less than about 10 mm.

11. A system comprising a plurality of the apparatuses of claim 8.

12. A method of treating seawater to reduce total dissolved solids comprising:

passing the seawater through a water treatment apparatus while applying energy in an amount less than about 7 kwh/kgal of filtrate to the apparatus; and

removing filtrate from the apparatus,

wherein the filtrate comprises less than about 1,000 ppm total dissolved solids.

13. The method of claim 12, wherein the water treatment apparatus comprises a nanofiltration device and an electrodeionization device.

14. The method of claim 12, wherein the filtrate comprises less than about 500 ppm total dissolved solids.

15. A method of treating seawater comprising:

reducing a concentration of one or more non-monovalent species from the seawater in a first stage; and

reducing a concentration of one or more monovalent species from the seawater in a second stage to produce water having a TDS of less than about 1,000 ppm,

wherein the first and second stages are performed at a net energy consumption rate of less than about 7 kwh/kgal of product water.

16. The method of claim 15, wherein the first stage comprises a nanofiltration device.

17. The method of claim 16, wherein the second stage comprises an electrodeionization device.

18. The method of claim 17, wherein a concentrate stream from the electrodeionization device is mixed with the seawater upstream of the first stage.

19. A method of treating water having dissolved solids therein comprising:

reducing a concentration of monovalent dissolved species from the water to produce a byproduct stream;

reducing a concentration of divalent dissolved species from the water; and

reducing a concentration of dissolved solids from the water to less than about 1,000 ppm in an electrodeionization device.

20. The method of claim 19, wherein the act of reducing the concentration of monovalent dissolved species comprises utilizing an electrodialysis device.

21. The method of claim 20, wherein the act of reducing the concentration of divalent dissolved species comprises utilizing a cation exchange column.

22. The method of claim 21, further comprising regenerating the cation exchange column with the byproduct stream.

23. The method of claim 15, wherein the first stage comprises a pressure-driven membrane system.

24. The method of claim 23, wherein the pressure-driven membrane system comprises at least one of a nanofiltration apparatus, a microfiltration apparatus, and an ultrafiltration apparatus.

25. The method of claim 19, wherein the step of reducing a concentration of divalent dissolved species from the water is performed through at least one pressure-driven apparatus selected from the group consisting of a nanofiltration apparatus, a microfiltration apparatus, and an ultrafiltration apparatus.

CLAIMS

1. A system for desalinating seawater comprising:

a source of seawater fluidly connected to a nanofiltration device, the source of seawater having a total dissolved solids in a range of from about 20,000 ppm to 40,000 ppm;

a nanofiltration device in fluid communication with the source of seawater and having a permeate outlet; and

an electrochemical device in fluid communication with the permeate outlet of the nanofiltration device, the electrochemical device having concentrating cells, and dilution cells with a thickness of less than about 10 mm to provide reduced electrical resistance, the system configured to consume less than 7 kwh/kgal of product water having a total dissolved solids in a range of from about 230 ppm to about 500 ppm.

2. The system of claim 1 further comprising a pretreatment device positioned upstream of the nanofiltration device and downstream from the source of seawater, the pretreatment device selected from the group consisting of a bed filter, a microfilter, a crossflow microfilter, a settling tank, and an aerator.

3. The apparatus of claim 1, wherein the electrochemical device comprises an electrodeionization apparatus.

4. A method of treating seawater to reduce total dissolved solids comprising:

treating the seawater in a nanofiltration device to provide a first permeate stream having a selectively reduced concentration of multivalent species;

treating the first permeate stream in an electrodialysis device to provide a second permeate stream having a selectively reduced concentration of monovalent species; and treating the second permeate stream in an electrodeionization device to produce a filtrate having a total dissolved solids in a range from about 230 ppm to about 500 ppm,

wherein less than about 7 kwh/kgal of filtrate is used to produce the filtrate from the seawater.

5. A method of treating seawater comprising:

selectively reducing a concentration of one or more non-monovalent species from the seawater in a first stage comprising a nanofiltration device to produce a filtrate; and

selectively reducing a concentration of one or more monovalent species from the filtrate in a second stage comprising an electrodeionization device to produce water having a total dissolved solids in a range from about 230 ppm to about 500 ppm,

wherein the first and second stages are operated at a net energy consumption rate of less than about 7 kwh/kgal of product water.

6. The method of claim 5, further comprising mixing a concentrate stream from the electrodeionization device with the seawater upstream of the first stage.

7. A method of desalinating seawater comprising:

selectively reducing a concentration of monovalent dissolved species from the seawater with an electrodialysis device to produce a byproduct and a first partially treated water stream having a reduced concentration of monovalent ions;

selectively reducing a concentration of divalent dissolved species from the first partially treated water stream with a cation exchange column to produce a second partially treated water stream having a reduced concentration of divalent ions;

regenerating the cation exchange column with the byproduct; and

reducing a concentration of dissolved species from the second partially treated water stream to less than about 1,000 ppm in an electrodeionization device.