

CLAIMS

What is claimed is:

1. A method of treating a waste stream containing perfluoroalkyl substances (PFAS) with an electrochemical separation device comprising a dilution compartment, a
6 concentration compartment, an ion exchange membrane positioned between the dilution compartment and the concentration compartment, and first and second electrodes, the method comprising:
 - directing the waste stream containing the PFAS to the dilution compartment;
 - directing a treatment stream to the concentration compartment; and
 - applying a voltage across the first and second electrodes to produce a dilute stream
- 12 being substantially free of the PFAS and a concentrate stream,
 - at least one of the waste stream and the treatment stream comprising a water miscible organic solvent.
2. The method of claim 1, wherein the waste stream is an aqueous solution and the treatment stream comprises the water miscible organic solvent.
- 18 3. The method of claim 1, wherein the waste stream comprises the water miscible organic solvent and the treatment stream is an aqueous solution.
4. The method of claim 3, wherein the water miscible organic solvent is an alcohol solution.
- 24 5. The method of claim 4, wherein the alcohol solution comprises at least one of methanol, ethanol, propanol, isopropanol, and butanol.
6. The method of claim 5, wherein the alcohol solution comprises methanol.
- 30 7. The method of claim 6, wherein the alcohol solution is 45% - 85% methanol by volume.
8. The method of claim 1, wherein the ion exchange membrane is 50% - 100% crosslinked.

9. The method of claim 8, wherein the ion exchange membrane has a thickness of 10 – 50 μm .
10. The method of claim 9, wherein the ion exchange membrane has a resistivity of about
6 3 – 10 $\Omega\text{-cm}^2$ when measured on direct current after equilibrium in a 0.5M NaCl solution at 25° C.
11. The method of claim 1, wherein applying the voltage across the first and second electrodes produces the dilute stream having at least 95% less PFAS by volume than the waste stream.
- 12
12. A method of concentrating perfluoroalkyl substances (PFAS) from a wastewater containing a concentration of PFAS, comprising:
passing the wastewater containing the PFAS over an ion exchange resin to uptake the PFAS onto the ion exchange resin;
regenerating the ion exchange resin by passing a regeneration stream comprising an
18 alcohol solution over the ion exchange resin to remove the PFAS and produce a waste stream comprising the alcohol solution containing the PFAS;
directing the waste stream to a dilution compartment of an electrochemical separation device;
directing an aqueous solution to a concentration compartment of the electrochemical separation device; and
24 applying a voltage across first and second electrodes of the electrochemical separation device through an ion exchange membrane positioned between the dilution compartment and the concentration compartment to produce a dilute stream comprising the alcohol solution being substantially free of the PFAS and a concentrate stream.
13. The method of claim 12, further comprising directing the dilute stream to regenerate
30 the ion exchange resin.
14. The method of claim 12, wherein the regeneration stream further comprises inorganic salts.

15. A perfluoroalkyl substances (PFAS) concentration system, comprising:
a column comprising an ion exchange resin, the column having a first inlet fluidly connectable to a source of a wastewater containing the PFAS, a second inlet fluidly connectable to a source of a regeneration solution comprising a water miscible organic solvent, a treated wastewater outlet, and a waste stream outlet; and
- 6 an electrochemical separation device comprising a dilution compartment having an inlet fluidly connected to the waste stream outlet and a dilute stream outlet fluidly connected to the second inlet of the column, a concentration compartment having an inlet fluidly connectable to a source of an aqueous solution and a concentrate stream outlet, an ion exchange membrane positioned between the dilution compartment and the concentration compartment, and first and a second electrodes positioned at distal ends of the
- 12 electrochemical separation device.
16. The system of claim 15, wherein the ion exchange membrane comprises a cationic functional monomer having a crosslinking group.
17. The system of claim 16, wherein the ion exchange membrane is 50% - 100%
- 18 crosslinked.
18. The system of claim 17, wherein the ion exchange membrane is 70% - 100% crosslinked.
19. The system of claim 18, wherein the ion exchange membrane has a thickness of 10 –
- 24 50 μm .
20. The system of claim 19, wherein the ion exchange membrane has a resistivity of about 3 – 10 $\Omega\text{-cm}^2$ when measured on direct current after equilibrium in a 0.5M NaCl solution at 25° C.
- 30 21. A method of facilitating treatment of a waste stream containing perfluoroalkyl substances (PFAS), the method comprising:
providing an electrochemical separation device comprising a dilution compartment, a concentration compartment, a 50% - 100% crosslinked ion exchange membrane positioned

between the dilution compartment and the concentration compartment, and first and second electrodes positioned at distal ends of the electrochemical separation device;

providing instructions to direct the waste stream containing the PFAS to the dilution compartment;

providing instructions to direct a treatment stream to the concentration compartment;

6 and

providing instructions to apply a voltage across the first and second electrodes to produce a dilute stream being substantially free of the PFAS and a concentrate stream,

at least one of the waste stream and the treatment stream comprising a water miscible organic solvent.

12 22. The method of claim 21, wherein the waste stream comprises the water miscible organic solvent.

23. The method of claim 22, further comprising providing instructions to direct the dilute stream to an ion exchange resin having the PFAS thereon.

18 24. The method of claim 21, wherein the treatment stream comprises the water miscible organic solvent.

25. The method of claim 24, wherein the waste stream is an aqueous solution containing the PFAS.

24 26. The method of claim 25, further comprising providing instructions to direct the concentrate stream to a post-treatment subsystem.