

CLAIMS

What is claimed is:

1. A disposable, virus-trapping membrane comprising:
a disposable, micro-porous filter membrane, wherein the filter membrane comprises a polymer substrate selected from the group consisting of polyvinylidene difluoride, polytetrafluorethylene, polyamides, polyamide-imides, polysulfones, polyethersulfones, and polyphenylsulfones; and
a ligand immobilized on the membrane, wherein the ligand is selected from the group consisting of tyrosinol, tryptophanol, octopamine, 2-aminobenzimidazole, 1,3-diamino-2-hydroxypropane, tris(2-aminoethyl)amine, and agmatine, and further wherein the ligand is dimensioned and configured to:
 - (a) irreversibly and selectively bind viruses and repel basic proteins;
 - (b) have a pKa sufficiently high to repel basic proteins via electrostatic charge repulsion; and
 - (c) yield a log-reduction value (LRV) of at least 1.0 for neutral viruses disposed in a solution comprising 50 mM salt.
2. The virus-trapping membrane of Claim 1, wherein the ligand is a multi-modal anion-exchange ligand.
3. The virus-trapping membrane of Claim 1, wherein the ligand has a positive charge at pH 7.
4. The virus-trapping membrane of Claim 1, wherein the ligand has a pKa of at least 10.0.

5. The virus-trapping membrane of Claim 1, wherein the ligand is dimensioned and configured to yield a log-reduction value (LRV) of at least 1.0 for neutral viruses disposed in a solution comprising 150 mM salt.

6. The virus-trapping membrane of Claim 1, wherein the ligand is dimensioned and configured to yield a log-reduction value (LRV) of at least 5.0 for neutral viruses disposed in a solution comprising 50 mM salt.

7. The virus-trapping membrane of Claim 1, wherein the ligand is dimensioned and configured to yield a log-reduction value (LRV) of at least 5.0 for neutral viruses disposed in a solution comprising 150 mM salt.

8. A disposable, virus-trapping membrane comprising:
a disposable, micro-porous filter membrane comprising polyvinylidene difluoride; and
a ligand immobilized on the membrane, wherein the ligand is selected from the group consisting of tyrosinol, tryptophanol, octopamine, 2-aminobenzimidazole, 1,3-diamino-2-hydroxypropane, tris(2-aminoethyl)amine, and agmatine, and further wherein the ligand:
(a) irreversibly and selectively binds viruses and repel basic proteins;
(b) is a multi-modal anion-exchange ligand;
(c) has a pKa of at least 10.0, whereby basic proteins are repelled from the ligand via electrostatic charge repulsion; and
(d) is dimensioned and configured to yield a log-reduction value (LRV) of at least 1.0 for neutral viruses disposed in a solution comprising 50 mM salt.

9. The virus-trapping membrane of Claim 8, wherein the ligand is dimensioned and configured to yield a log-reduction value (LRV) of at least 1.0 for neutral viruses disposed in a solution comprising 150 mM salt.

10. The virus-trapping membrane of Claim 8, wherein the ligand is dimensioned and configured to yield a log-reduction value (LRV) of at least 5.0 for neutral viruses disposed in a solution comprising 50 mM salt.

11. The virus-trapping membrane of Claim 8, wherein the ligand is dimensioned and configured to yield a log-reduction value (LRV) of at least 5.0 for neutral viruses disposed in a solution comprising 150 mM salt.

12. A method of removing viruses from a solution suspected of containing viruses, the method comprising:

contacting a solution suspected of containing viruses with a virus-trapping membrane for a time sufficient to yield a log-reduction value (LRV) of at least 1.0 for neutral viruses disposed in the solution when the solution comprises from 0 to 50 mM salt, the virus-trapping membrane comprising:

a disposable, micro-porous filter membrane; and

a ligand immobilized on the membrane, wherein the ligand is selected from the group consisting of tyrosinol, tryptophanol, octopamine, 2-aminobenzimidazole, 1,3-diamino-2-hydroxypropane, tris(2-aminoethyl)amine, and agmatine, and further wherein the ligand is dimensioned and configured to irreversibly and selectively bind viruses and repel basic proteins, and has a pKa sufficiently high to repel basic proteins present in the solution via electrostatic charge repulsion.

13. The method of Claim 12, wherein the solution is contacted with the virus-trapping membrane for a time sufficient to yield a log-reduction value (LRV) of at least 1.0 for neutral viruses disposed in the solution when the solution comprises from 0 to 150 mM salt.

14. The method of Claim 12, wherein the solution is contacted with the virus-trapping membrane for a time sufficient to yield a log-reduction value (LRV) of at least 5.0 for neutral viruses disposed in the solution when the solution comprises from 0 to 50 mM salt.

15. The method of Claim 12, wherein the solution is contacted with the virus-trapping membrane for a time sufficient to yield a log-reduction value (LRV) of at least 5.0 for neutral viruses disposed in the solution when the solution comprises from 0 to 150 mM salt.

16. The method of Claim 12, wherein the ligand immobilized on the membrane is selected from the group consisting of tris(2-aminoethyl)amine and agmatine.

17. The virus-trapping membrane of Claim 1 wherein the filter membrane comprises a membrane pore size of from 0.1 μm to 10 μm .

18. The method of Claim 12 wherein the filter membrane comprises a membrane pore size of from 0.1 μm to 10 μm .

CLAIMS

1. A disposable, virus-trapping membrane comprising:
a disposable, micro-porous filter membrane; and
a multi-modal anion-exchange ligand immobilized on the membrane, wherein the ligand is dimensioned and configured to:
 - (a) bind neutral viruses;
 - (b) have a pKa sufficiently high to repel basic proteins via electrostatic charge repulsion; and
 - (c) yield a log-reduction value (LRV) of at least 1.0 for the neutral viruses disposed in a solution comprising 50 mM salt.
2. The virus-trapping membrane of claim 1, wherein the ligand has a positive charge at pH 7.
3. The virus-trapping membrane of claim 1, wherein the ligand has a pKa of at least 10.0.
4. The virus-trapping membrane of claim 1, wherein the filter membrane comprises a polymer substrate selected from the group consisting of polyvinylidene difluoride, polytetrafluorethylene, polyamides, polyamide-imides, polysulfones, polyethersulfones, and polyphenylsulfones.
5. The virus-trapping membrane of claim 1, wherein the ligand is dimensioned and configured to yield a log-reduction value (LRV) of at least 1.0 for neutral viruses disposed in a solution comprising 150 mM salt.
6. The virus-trapping membrane of claim 1, wherein the ligand is dimensioned and configured to yield a log-reduction value (LRV) of at least 5.0 for neutral viruses disposed in a solution comprising 50 mM salt.
7. The virus-trapping membrane of claim 1, wherein the ligand is dimensioned and configured to yield a log-reduction value (LRV) of at least 5.0 for neutral viruses disposed in a solution comprising 150 mM salt.

8. The virus-trapping membrane of claim 1, wherein the ligand is selected from the group consisting of tyrosinol, tryptophanol, octopamine, 2-aminobenzimidazole, 1,3-diamino-2-hydroxypropane, tris(2-aminoethyl)amine, and agmatine.

9. A disposable, virus-trapping membrane comprising:
a disposable, micro-porous filter membrane; and
a ligand immobilized on the membrane, wherein the ligand is selected from the group consisting of tyrosinol, tryptophanol, octopamine, 2-aminobenzimidazole, 1,3-diamino-2-hydroxypropane, tris(2-aminoethyl)amine, and agmatine, and further wherein the ligand:

- (a) binds neutral viruses;
- (b) is a multi-modal anion-exchange ligand;
- (c) has a pKa sufficiently high to repel basic proteins via electrostatic charge repulsion; and
- (d) yields a log-reduction value (LRV) of at least 1.0 for the neutral viruses disposed in a solution comprising 50 mM salt.

10. The virus-trapping membrane of claim 9, wherein the ligand is selected from the group consisting of tryptophanol, 2-aminobenzimidazole, tris(2-aminoethyl)amine, and agmatine, and further wherein the ligand is dimensioned and configured to yield a log-reduction value (LRV) of at least 1.0 for neutral viruses disposed in a solution comprising 150 mM salt.

11. The virus-trapping membrane of claim 9, wherein the ligand is selected from the group consisting of tris(2-aminoethyl)amine and agmatine, and further wherein the ligand is dimensioned and configured to yield a log-reduction value (LRV) of at least 5.0 for neutral viruses disposed in a solution comprising 50 mM salt.

12. The virus-trapping membrane of claim 9, wherein the ligand is selected from the group consisting of tris(2-aminoethyl)amine and agmatine, and further wherein the ligand is dimensioned and configured to yield a log-reduction value (LRV) of at least 5.0 for neutral viruses disposed in a solution comprising 150 mM salt.

13. A method of removing viruses from a solution suspected of containing viruses, the method comprising:

contacting a solution suspected of containing viruses with virus-trapping membrane comprising a disposable, micro-porous filter membrane and a multi-modal anion-exchange ligand

immobilized on the membrane, wherein the ligand is dimensioned and configured to bind neutral viruses, has a pKa sufficiently high to repel basic proteins present in the solution via electrostatic charge repulsion, and yields a log-reduction value (LRV) of at least 1.0 for the neutral viruses disposed in a solution comprising 50 mM salt.

14. The method of claim 13, wherein the solution is contacted with the virus-trapping membrane for a time sufficient to yield a log-reduction value (LRV) of at least 1.0 for neutral viruses disposed in the solution when the solution comprises from 0 to about 50 mM salt.

15. The method of claim 13, wherein the solution is contacted with the virus-trapping membrane for a time sufficient to yield a log-reduction value (LRV) of at least 1.0 for neutral viruses disposed in the solution when the solution comprises from 0 to about 150 mM salt.

16. The method of claim 13, wherein the solution is contacted with the virus-trapping membrane for a time sufficient to yield a log-reduction value (LRV) of at least 5.0 for neutral viruses disposed in the solution when the solution comprises from 0 to about 50 mM salt.

17. The method of claim 13, wherein the solution is contacted with the virus-trapping membrane for a time sufficient to yield a log-reduction value (LRV) of at least 5.0 for neutral viruses disposed in the solution when the solution comprises from 0 to about 150 mM salt.

18. The method of claim 13, wherein the solution is contacted with a disposable, micro-porous filter membrane comprising polyvinylidene difluoride; and the ligand immobilized on the membrane is selected from the group consisting of tyrosinol, tryptophanol, octopamine, 2-aminobenzimidazole, 1,3-diamino-2-hydroxypropane, tris(2-aminoethyl)amine, and agmatine.

19. The method of claim 18, wherein the ligand immobilized on the membrane is selected from the group consisting of tris(2-aminoethyl)amine and agmatine.

20. A disposable, virus-trapping membrane comprising:
a disposable, micro-porous filter membrane;
a multi-modal exchange ligand immobilized on the membrane, wherein the ligand is selected from the group consisting of tryptophanol, 2-aminobenzimidazole, tris(2-aminoethyl)amine, and agmatine, and further wherein the ligand is dimensioned and configured to:

- (a) bind neutral viruses;

(b) have a pKa sufficiently high to repel basic proteins via electrostatic charge repulsion; and

(c) yield a log-reduction value (LRV) of at least 1.0 for the neutral viruses disposed in a solution comprising 150 mM salt.

21. The virus-trapping membrane of claim 20, wherein the ligand is dimensioned and configured to yield a log-reduction value (LRV) of at least 5.0 for the neutral viruses disposed in a solution comprising 150 mM salt.

22. The virus-trapping membrane of claim 20, wherein the ligand is selected from the group consisting of tris(2-aminoethyl)amine and agmatine, and is dimensioned and configured to yield a log-reduction value (LRV) of at least 5.0 for the neutral viruses disposed in a solution comprising 150 mM salt.