

CLAIMS

1. A reverse-osmosis system comprising:
 - multiple reverse-osmosis assemblies, each reverse-osmosis assembly comprising:
 - a reverse-osmosis stage having a semi-permeable membrane, a feed inlet, a permeate outlet and a concentrate outlet, wherein the feed inlet is configured to receive feed water having a feed-water flow rate;
 - a concentrate valve configured to control the pressure of the concentrate outlet;
 - a sensor array having:
 - a feed pressure sensor;
 - a feed flow sensor;
 - at least one of: a feed salinity and a conductivity sensor;
 - a feed temperature sensor;
 - at least two flow sensors configured to measure at least two of: feed flow, permeate flow, and concentrate flow;
 - at least one of: a permeate salinity and a conductivity sensor;
 - a differential pressure sensor configured to measure the difference between the feed pressure and the concentrate pressure; and
 - a permeate pressure sensor; and
 - a controller configured:
 - to receive information from the sensor arrays;
 - to calculate, from the received information, one or more of: an A-Value, a B-value and a normalized differential pressure value, for each reverse-osmosis stage;
 - to determine a fouling parameter for each reverse-osmosis stage based on one or more of: the A-Value, the B-value and the normalized differential pressure value; and
 - to control flow through each of the reverse-osmosis assemblies based on the determined fouling parameters to meet a predetermined criterion for total permeate production for the reverse-osmosis system.
2. The system of claim 1, wherein the controller is configured to control the flow through each of the reverse-osmosis assemblies comprises by adjusting a recovery ratio of each of the reverse-osmosis assemblies.
3. The system according to any one of claims 1-2, wherein the controller is configured to control the flow through each of the reverse-osmosis assemblies comprises by adjusting feed flow provided to each of the reverse-osmosis assemblies.

4. The system according to any one of claims 1-3, wherein the controller is configured to use machine learning to predict the response of controlling the flow through each of the reverse-osmosis assemblies.
5. The system according to any one of claims 1-4, wherein the controller is configured to enable control of flow through each of the reverse-osmosis assemblies based on the received information and on previous behaviour of the system to meet predetermined permeate flow and permeate salinity criteria and to reduce energy consumption.
6. The system according to any one of claims 1-5, wherein the controller is configured to increase permeate production of the reverse-osmosis assemblies which have a fouling parameter indicative of less fouling and increase concentrate production of the reverse-osmosis assemblies which have a fouling parameter indicative of more fouling.
7. The system according to any one of claims 1-6, wherein the controller is configured to decrease flow through the feed inlets of the reverse-osmosis assemblies which have a fouling parameter indicative of less fouling and increase flow through the feed inlets of the reverse-osmosis assemblies which have a fouling parameter indicative of more fouling.
8. The system according to any one of claims 1-7, wherein the controller is configured to control the flows through the reverse osmosis assemblies in real time to meet predetermined total permeate flow and total permeate salinity criteria and to reduce cleaning.
9. The system according to any one of claims 1-8, wherein the sensor array comprises an energy sensor configured to measure the energy consumption of the system.
10. The system according to any one of claims 1-9, wherein the sensor array comprises feed temperature sensor.
11. A method of controlling a reverse-osmosis system comprising:
 - a reverse-osmosis stage comprising a semi-permeable membrane, a feed inlet, a permeate outlet and a concentrate outlet, wherein the feed inlet is configured to receive feed water powered by a feed pump;
 - a concentrate valve configured to control the pressure of the concentrate outlet flow;
 - the method comprising:
 - measuring a feed pressure;
 - measuring a feed flow;
 - measuring a feed salinity and/or conductivity;

- measuring a feed temperature;
- measuring at least two of: feed flow, permeate flow, and concentrate flow;
- measuring a permeate salinity and/or conductivity;
- measuring a differential pressure configured to measure the difference between the feed pressure and the concentrate pressure;
- measuring a permeate pressure;
- determining a fouling parameter for each reverse-osmosis stage based on one or more of: an A-Value, a B-value and a normalized differential pressure value; and
- controlling the flow through adjust flow through each of the reverse-osmosis assemblies based on the determined fouling parameters to meet a predetermined criterion for total permeate production for the reverse-osmosis system.

12. A computer program comprising computer program code configured to run in conjunction with a reverse-osmosis system, the reverse-osmosis system comprising:

- a reverse-osmosis stage comprising a semi-permeable membrane, a feed inlet, a permeate outlet and a concentrate outlet, wherein the feed inlet is configured to receive feed water powered a feed pump;

- a concentrate valve configured to control the pressure of the concentrate outlet flow;

- a sensor array having:

- a feed pressure sensor;

- a feed flow sensor;

- a feed salinity and/or conductivity sensor;

- a feed temperature sensor;

- at least two flow sensors configured to measure at least two of: feed flow, permeate flow, and concentrate flow;

- a permeate salinity and/or conductivity sensor;

- a differential pressure sensor configured to measure the difference between the feed pressure and the concentrate pressure;

- a permeate pressure sensor;

- wherein the computer program code is configured to receive information from the sensor arrays; and

- to determine a fouling parameter for each reverse-osmosis stage based on one or more of: an A-Value, a B-value and a normalized differential pressure; and

to control the flow through adjust flow through each of the reverse-osmosis assemblies based on the determined fouling parameters to meet a predetermined criterion for total permeate production for the reverse-osmosis system.

13. A reverse-osmosis system comprising:

a reverse-osmosis stage having a semi-permeable membrane, a feed inlet, a permeate outlet and a concentrate outlet, wherein the feed inlet is configured to receive feed water having a feed-water flow rate;

a concentrate valve configured to control the pressure of the concentrate outlet;

a sensor array having:

a feed pressure sensor;

a feed flow sensor;

at least one of: a feed salinity and a conductivity sensor;

a feed temperature sensor;

at least two flow sensors configured to measure at least two of: feed flow, permeate flow, and concentrate flow;

at least one of: a permeate salinity and a conductivity sensor;

a differential pressure sensor configured to measure the difference between the feed pressure and the concentrate pressure; and

a permeate pressure sensor; and

a controller configured:

to receive information from the sensor array; and

to determine a fouling parameter based on one or more of: an A-Value, a B-value and a normalized differential pressure; and

to calculate how the fouling parameter would change as a function of permeate production for various flow rates through the feed inlet and recovery ratios, based on previous behaviour of the system.

14. The reverse-osmosis system of claim 13, wherein the system is configured to calculate an estimate of when an inflection point will occur in the fouling parameter as a function of cumulative permeate flow due to membrane fouling based on previous behaviour of the system.

15. The reverse-osmosis system of claim 14, wherein the system is configured to calculate the future energy consumption of the reverse-osmosis system based on the estimated inflection point; and to determine the optimum time to clean the reverse-osmosis stage, based on the calculated future energy consumption.

16. The reverse-osmosis system according to any one of claims 13-15, wherein the system is configured to calculate an estimate of when a change will occur in the rate of change of fouling parameter as a function of cumulative permeate flow due to membrane fouling based on previous behaviour of the system.
17. The reverse-osmosis system according to any one of claims 13-16, wherein the calculation of how the fouling parameter would change as a function of permeate production is based on one or more of: the feed salinity and the feed conductivity.
18. The reverse-osmosis system according to any one of claims 13-17, wherein the calculation of how the fouling parameter would change as a function of permeate production is based on the feed temperature.