CLAIMS:

1. A system for determining a filter status, comprising:

a database configured to electronically store data, the data including past performance data of one or more water filtration elements; and

a processing device in communication with the database, the processing device is configured to:

receive as input the past performance data;

identify one or more data points within the past performance data indicative of a cleaning event for the one or more water filtration elements;

divide the past performance data into individual data segments, each of the individual data segments representing data of the past performance data in-between respective identified cleaning events;

fit a mathematical function to each of the individual data segments; and

identify a type of fouling occurring during each of the individual data segments based on the mathematical function fitted to the respective individual data segment.

2. The system of claim 1, wherein the processing device is further configured to normalize the past performance data to conditions at startup of the one or more water filtration elements before identifying the cleaning events; and/or wherein the processing device is further configured to account for a variation of at least one of a feedwater temperature, a feedwater composition, or a feed pressure, when normalizing the past performance data.

3. The system of any preceding claim, wherein the processing device is further configured to identify and remove physically inconsistent data points from the past performance data before identifying the cleaning events; wherein the system preferably is a reverse osmosis (RO) or a nanofiltration (NF) system, and wherein the physically inconsistent data point is removed from the past performance data if one or more of the following conditions is not met:

the feed flow is greater than concentrate flow;

the feed flow is greater than permeate flow;

the feed pressure is greater than concentrate pressure; and

the feed pressure is greater than permeate pressure; or

wherein the system is an ultrafiltration (UF) or a microfiltration (MF) system, and wherein the physically inconsistent data point is removed from the past performance data if one or more of the following conditions is not met:

the feed pressure is greater than the trans-membrane pressure;

the filtrate pressure is greater than the trans-membrane pressure; and

the feed turbidity is greater than the filtrate turbidity.

4. The system of any preceding claim, wherein the processing device is further configured to identify and remove statistical outlier data points from the past performance data before identifying the cleaning events, wherein identifying and removing the statistical outlier data points from the past performance data preferably comprises:

calculating a percentage change of a data point (y_t) from a previous data point (y_{t-1});

calculating a percentage change of a next data point (y_{t+1}) from the data point (y_t);

comparing a previous percentage change with a drop limit value; and

identifying the data point (y_t) as an outlier if the previous and next percentage changes exceed the drop limit.

5. The system of any preceding claim, wherein identifying the cleaning events comprises:

applying a differencing series method to a normalized pressure drop (dP) and a normalized permeate flow (Pf) from the past performance data, wherein applying the differencing series method includes:

calculating a difference between the data point (y_t) and the previous data point (y_{t-1}) to generate a differencing series for the normalized pressure drop (dP) and the normalized permeate flow (Pf);

calculating an average and a standard deviation for the differencing series for the normalized pressure drop (dP) and the normalized permeate flow (Pf);

comparing each value in the differencing series for the normalized pressure drop (dP) and the normalized permeate flow (Pf) to a sum of corresponding values in the differencing series and a product of a differencing constant and a corresponding standard deviation of the differencing series;

determining if a gap exists in the dataset; and

determining if the gap is wider than a MCE reference time.

6. The system of any preceding claim, wherein the system is the ultrafiltration (UF) or the microfiltration (MF) system, wherein identifying the cleaning events comprises:

applying a differencing series method to a transmembrane pressure drop (TMP), a feed turbidity, and a permeability from the past performance data, wherein applying the differencing series method includes:

calculating a difference between time values between the data point (t) and previous data points (t-x) to generate time differencing series;

calculating the difference between the data point (y_t) and previous data points (y_{t-x}) to generate the differencing series for transmembrane pressure drop (TMP), feed turbidity, and permeability;

comparing each value in the differencing series of time, transmembrane pressure drop (TMP), feed turbidity, and permeability to threshold values Backwash, CEB, and CIP MCE events;

determining if comparison matches backwash MCE criteria;

determining if comparison matches CEB MCE criteria; and

determining if comparison matches CIP MCE criteria.

7. The system of any preceding claim, wherein the processing device is further configured to analyze a coefficient of determination or an Akaike Information Criterion (AIC) of the mathematical function and calculate derivatives of the mathematical function with respect to time; or wherein the processing device is further configured to identify the type of fouling based on the derivatives of the coefficient of determination or of the Akaike Information Criterion (AIC); and/or wherein the one or more water filtration elements include at least one element selected from the group consisting of an ultrafiltration element, a microfiltration element, a reverse osmosis element, a nanofiltration element, and a hyperfiltration element.

8. The system of any preceding claim, further comprising one or more sensors configured to detect and transmit data for one or more of pressure drop, salt passage, and permeate flow associated with each of the one or more water filtration elements for storage in the database as the past performance data.

9. The system of any preceding claim, wherein the system is a reverse osmosis (RO) or a nanofiltration (NF) system, and:

the past performance data includes pressure drop, salt passage, and permeate flow for each of the one or more water filtration elements; and

(a) if no change in the pressure drop, salt passage, and permeate flow is detected, the processing device identifies a no fouling condition; and/or

(b) if an increase in the pressure drop fits a 2^{nd} order polynomial function, the processing device identifies the type of fouling as biofouling; and/or

(c) if a decrease of the salt passage fits a 2^{nd} order polynomial function, the processing device identifies the type of fouling as organic fouling; and/or

(d) if a rapid increase in the pressure drop of first position elements fits a 1^{st} order polynomial function, the processing device defines the type of fouling as particulate fouling; and/or

(e) if a gradual increase in the pressure drop of tail position elements fits a 1^{st} order polynomial function, the processing device identifies the type of fouling as scaling; and/or

(f) if a rapid increase in the permeate flow fits a 1st order polynomial function and a rapid increase in the salt passage fits a 1st order polynomial function, the processing device identifies the type of fouling as physical integrity failure.

10. The system of any of claims 1 through 7, wherein the system is an ultrafiltration (UF) or a microfiltration (MF) system, wherein: the past performance data includes one or more of feed pressure, feed turbidity, transmembrane pressure drop, filtrate pressure, and filtrate turbidity; and wherein the physically inconsistent data point is removed from the past performance data when one or more of the following conditions is not met:

the feed pressure is no less than transmembrane pressure drop;

the transmembrane pressure drop is less than or equal to the difference between the feed pressure and filtrate pressure; and

the feed turbidity is greater than filtrate turbidity; and/or wherein the system is the ultrafiltration (UF) or the microfiltration (MF) system, wherein the past performance data includes one or more of feed pressure, feed turbidity, transmembrane pressure drop, filtrate pressure, and filtrate turbidity; and wherein the processing device identifies the type of fouling as fast removal or cake formation fouling when one or more of the following conditions is met:

the increase in the transmembrane pressure during filtration fits a first order polynomial function; transmembrane pressure during backwash remains constant; transmembrane pressure during backwash and CEC remains constant; filtrate turbidity remains constant or remains below 1 NTU; and cleanability remains constant or remains between 60 to 95%; and/or wherein the system is the ultrafiltration (UF) or the microfiltration (MF) system, wherein the past performance data includes one or more of feed pressure, feed turbidity, transmembrane pressure drop, filtrate pressure, and filtrate turbidity; and wherein the processing device identifies the type of fouling as slow removal, biologic or organic fouling when one or more of the following conditions is met: the increase in the transmembrane pressure during filtration fits a linear function, a second order polynomial function, or another non-linear function; the increases in transmembrane pressure during

backwash and during CEC fit a linear or non-linear function when oxidants or caustics are not used; filtrate turbidity remains constant or below 1 NTU; and cleanability remains below 60% or fits a first order polynomial; and/or wherein the system is the ultrafiltration (UF) or the microfiltration (MF) system, wherein the past performance data includes one or more of feed pressure, feed turbidity, transmembrane pressure drop, filtrate pressure, and filtrate turbidity; and wherein the processing device identifies the type of fouling as irreversible or inorganic fouling when one or more of the following conditions is met:

the increase in the transmembrane pressure during filtration fits a linear function, a second order polynomial function or another non-linear function; the increase in transmembrane pressure during backwash fits a linear or non-linear function; the increase in transmembrane pressure during CEC fits a linear or non-linear function when acids are not used; filtrate turbidity remains constant or below 1 NTU; and cleanability fits a second order polynomial or remains below 60%; and/or wherein the system is the ultrafiltration (UF) or the microfiltration (MF) system, wherein the past performance data includes one or more of feed pressure, feed turbidity, transmembrane pressure drop, filtrate pressure, and filtrate turbidity; and

wherein the processing device identifies the type of failure as chemical degradation when one or more of the following is true:

the transmembrane pressure during filtration remains constant; cleanability remains constant; filtrate turbidity increases in a linear fashion; or filtrate turbidity shows a gradual increase; and/or wherein the system is the ultrafiltration (UF) or the microfiltration (MF) system, wherein the past performance data includes one or more of feed pressure, feed turbidity, transmembrane pressure drop, filtrate pressure, and filtrate turbidity; and wherein the processing device identifies the type of failure as physical integrity failure when one or more of the following conditions is met: the transmembrane pressure decreases in a linear fashion; cleanability remains constant; filtrate turbidity shows a rapid increase; and filtrate turbidity increases in a non-linear fashion.

11. The system of any preceding claim, wherein the processing device is further configured to:

receive as input current performance data of the one or more water filtration elements as received from one or more sensors;

analyze the current performance data based on the previous analysis of the past performance data and the identification of the type of fouling occurring during each of the individual data segments;

estimate a current type of fouling occurring at the one or more water filtration elements; and

output a recommendation for a cleaning procedure specific to the current type of fouling occurring at the one or more water filtration elements.

12. The system of any preceding claim, wherein the processing device is further configured to detect a type of scaling, or a no fouling, or no scaling condition.

13. The system of any preceding claim, wherein the data further includes a configuration of the membrane filtration units; an operation condition(s) and protocol(s) of the system; or both the configuration of the membrane filtration units and the operation condition(s) and protocol(s) of the system; and/or further comprising artificial intelligence, machine learning capabilities, or both artificial intelligence, machine learning capabilities, wherein the artificial intelligence or machine learning capabilities operate to improve identification of fouling types, predictability of fouling events or both identification of fouling types and predictability of fouling events.

14. A method for determining a filter status, comprising:

receiving as input to a system for determining a filter status past performance data of one or more water filtration elements, the system for determining the filter status including (i) a database configured to electronically store the past performance data, and (ii) a processing device in communication with the database;

identifying one or more data points within the past performance data indicative of a cleaning event for the one or more water filtration elements;

dividing the past performance data into individual data segments, each of the individual data segments representing data of the past performance data in-between respective identified cleaning events;

fitting a mathematical function to each of the individual data segments; and

identifying a type of fouling occurring during each of the individual data segments based on the mathematical function fitted to the respective individual data segment, preferably further comprising identifying a type of scaling, or a no fouling, or a no scaling condition.

15. A non-transitory computer-readable medium storing instructions for determining a filter status that are executable by a processing device, wherein execution of the instructions by the processing device causes the processing device to:

receive as input to a system for determining a filter status past performance data of one or more water filtration elements, the system for determining the filter status including (i) a database configured to electronically store the past performance data, and (ii) the processing device in communication with the database;

identify one or more data points within the past performance data indicative of a cleaning event for the one or more water filtration elements;

divide the past performance data into individual data segments, each of the individual data segments representing data of the past performance data in-between respective identified cleaning events;

fit a mathematical function to each of the individual data segments; and

identify a type of fouling occurring during each of the individual data segments based on the mathematical function fitted to the respective individual data segment, wherein the processing device preferably is further configured to identify a type of scaling, or a no fouling, or a no scaling condition.