DESCRIPTION

CONTROL METHOD AND CONTROL APPARATUS FOR FILTRATION MEMBRANE SYSTEM, AND FILTRATION MEMBRANE SYSTEM

TECHNICAL FIELD

[0001] The present invention relates to a control method and control apparatus for a filtration membrane system, and a filtration membrane system.

BACKGROUND ART

[0002] For example, as membrane filtration technology for water purification processes, a coagulation-membrane filtration method in which coagulation treatment is performed prior to membrane filtration is known (refer, for example, to Patent Literature 1). In the coagulation-membrane filtration method, a coagulant is injected into raw water, the raw water and coagulant are mixed, and after turbid matter, colloids, dissolved substances, and the like in the raw water react with the coagulant to form aggregates, filtrate is obtained by filtering water containing the aggregates through a membrane.

CITATION LIST

Patent Literature

[0003] Patent Literature 1: Japanese Patent Application Laid-Open No. 2014-168729

SUMMARY OF INVENTION

Technical Problem

[0004] In the coagulation-membrane filtration method, due to the passage of

operation time, aggregates that have flowed into the membrane filtration process adhere to the surfaces and pores of the filtration membrane, and a phenomenon (fouling) can occur in which the filtration membrane is blocked by deposited aggregates, resulting in a significant reduction in water permeation performance. From the viewpoint of suppressing fouling and realizing stable membrane filtration, it is preferable that the filtration membrane system can be operated in a state in which aggregates do not easily adhere to the filtration membrane.

[0005] The present invention has been made in view of the above-described circumstances, and provides a control method for a filtration membrane system that enables membrane filtration in a state in which aggregates do not easily adhere to the filtration membrane and that can suppress fouling.

Solution to Problem

[0006] One aspect of the present invention is a control method for a filtration membrane system comprising a coagulant injection unit configured to inject a coagulant into raw water, and a filtration membrane configured to obtain filtrate by filtration treatment of coagulation-treated water of the raw water containing aggregates formed by injection of the coagulant. The control method comprises a control step of controlling injection rates of at least one of the coagulant and a pH adjusting agent so that the zeta potential of the aggregates falls within a target range corresponding to the material of the filtration membrane, as preprocessing before filtration treatment by the filtration membrane.

[0007] The above-described control method may further comprise a preparation step in which a correspondence relationship between the pH values of the coagulation-treated water and the zeta potential of the aggregates is acquired. In addition, in the

above-described control step, the pH values of the coagulation-treated water may be monitored, and injection rates of at least one of the coagulant and the pH adjusting agent may be controlled so that the monitored pH values of the coagulation-treated water fall within a pH value range corresponding to the target range, based on the correspondence relationship.

[0008] The above-described filtration membrane may be an alumina-based ceramic membrane. In addition, in the above-described control step, injection rates of at least one of the coagulant and the pH adjusting agent may be controlled so that the zeta potential of the aggregates becomes -7 mV or greater. Furthermore, in the above-described control step, injection rates of at least one of the coagulant and the pH adjusting agent may be controlled so that the zeta potential of the aggregates falls within the negative-side region of the target range.

[0009] In the above-described control step, a pH adjusting agent may be injected into the raw water at a predetermined ratio, and the injection rate of the coagulant may be controlled so that the zeta potential of the aggregates falls within a target range corresponding to the material of the filtration membrane.

[0010] In the above-described control step, a coagulant may be injected into the raw water at a predetermined ratio, and the injection rate of the pH adjusting agent may be controlled so that the zeta potential of the aggregates falls within a target range corresponding to the material of the filtration membrane.

[0011] The filtration membrane system according to the above-described control method may further comprise a sedimentation tank in which solid-liquid separation of the aggregates is performed upstream of the filtration membrane. In addition, the filtration membrane may perform filtration treatment of the coagulation-treated water after the solid-liquid separation.

[0012] Another aspect of the present invention is a control apparatus of a filtration membrane system comprising a coagulant injection unit configured to inject a coagulant into raw water, and a filtration membrane configured to obtain filtrate by filtration treatment of coagulation-treated water of the raw water containing aggregates formed by injection of the coagulant. The control apparatus comprises a control unit configured to adjust the injection rate of at least one of the coagulant and the pH adjusting agent so that the zeta potential of the aggregates falls within a target range corresponding to the material of the filtration membrane, upstream of filtration treatment by the filtration membrane.

[0013] The above-described control apparatus may further comprise a storage unit configured to hold correspondence relationship data between the pH values of the coagulation-treated water and the zeta potential of the aggregates. In addition, the control unit may acquire the pH values of the coagulation-treated water, and may control the injection rate of at least one of the coagulant and the pH adjusting agent so that the pH values of the coagulation-treated water fall within a pH value range corresponding to the target range, based on the correspondence relationship.

[0014] A filtration membrane system of yet another aspect of the present invention comprises a coagulant injection unit configured to inject a coagulant into raw water, a filtration membrane configured to obtain filtrate by filtration treatment of coagulation-treated water of the raw water containing aggregates formed by injection of the coagulant, and the above-described control apparatus.

Advantageous Effects of Invention

[0015] According to one aspect of the present invention, a control method for a filtration membrane system that enables membrane filtration in a state in which

aggregates do not easily adhere to the filtration membrane and that can suppress fouling can be provided.

BRIEF DESCRIPTION OF DRAWINGS

[0016] FIG. 1 is a diagram showing a configuration example of a filtration membrane system of a first embodiment.

FIG. 2 is a diagram showing a configuration example of a filtration membrane system of a second embodiment.

FIG. 3 is a diagram showing a configuration example of a filtration membrane system of a third embodiment.

FIG. 4 is a diagram showing a configuration example of a filtration membrane system of a fourth embodiment.

FIG. 5 (a) is a flow diagram showing an example of a control method for the filtration membrane system of the first embodiment, (b) is a flow diagram showing an example of a control method for the filtration membrane system of the third embodiment, and (c) is a flow diagram showing an example of a control method for the filtration membrane system of the fourth embodiment.

FIG. 6 is a graph showing coagulant injection rates, the zeta potential of aggregates, and the pH of coagulation-treated water in coagulation-treated water of a first example.

FIG. 7 is a diagram showing the zeta potential of aggregates and rate of increase of the transmembrane pressure of the filtration membrane when pH of coagulation-treated water into which the coagulant has been injected is changed in the first example.

FIG. 8 is a graph showing coagulant injection rates, the zeta potential of aggregates, and pH of coagulation-treated water in coagulation-treated water of a second example.

FIG. 9 is a graph showing coagulant injection rates, the zeta potential of aggregates, and

pH of coagulation-treated water in coagulation-treated water of a third example.

DESCRIPTION OF EMBODIMENTS

[0017] Hereinafter, embodiments of the present invention will be explained with reference to the drawings. In the embodiments, for easy understanding, structures and elements other than the main part of the present invention will be explained in a simplified or omitted manner. In addition, in each drawing, the same elements are denoted by the same reference numerals. It should be noted that, shapes, dimensions, and the like of the respective elements illustrated in the respective drawings are schematically illustrated, and do not indicate actual shapes, dimensions, and the like.

(First Embodiment)

[0018] In the first embodiment, coagulant injection rates are controlled so that the zeta potential of aggregates generated by coagulant injection falls within a target range corresponding to the material of a filtration membrane in coagulation treatment upstream of membrane filtration treatment in a filtration membrane system that combines coagulation treatment and membrane filtration treatment. In the first embodiment, adherence of residual aggregates to the filtration membrane surface and pores is reduced by adjusting the zeta potential of residual aggregates contained in raw water into which a coagulant has been injected (coagulation-treated water) that flows into the membrane filtration process to fall within an appropriate range corresponding to the material of the filtration membrane. Accordingly, fouling due to blocking of the filtration membrane is suppressed, and stable membrane filtration can be realized.

[0019] FIG. 1 is a diagram showing a configuration example of the filtration membrane system of the first embodiment. The filtration membrane system 1 of the first embodiment comprises a coagulant injection unit 2, a retention tank 4, a

sedimentation tank 5, a membrane filtration tank 6, and a control apparatus 10.

[0020] Raw water including turbid matter, colloids, and dissolved substances is supplied to the filtration membrane system 1 via a raw water pipe 7. The downstream side of the raw water pipe 7 is connected to the retention tank 4. As an example, the raw water may be water supply raw water such as river water, groundwater, or lake water, or may be wastewater such as domestic wastewater, rainwater, or factory wastewater.

[0021] The coagulant injection unit 2 is connected to the raw water pipe 7 upstream of the retention tank 4, and the coagulant injection unit 2 injects a coagulant into raw water flowing through the raw water pipe 7. At the downstream side of the coagulant injection unit 2, turbid matter, colloids, and dissolved substances included in the raw water react with the coagulant by the raw water and the coagulant being mixed. Accordingly, aggregates (flocs) are generated in the raw water.

[0022] Examples of the coagulant include ferric chloride, polyferric sulfate, polysilica iron, aluminum sulfate, polyaluminum chloride, high-basicity polyaluminum chloride, or mixtures thereof. Coagulation aids such as polymers may be added to the above-described coagulants. It should be noted that in the present embodiment, a case in which ferric chloride is applied as the coagulant will be explained.

[0023] The retention tank 4 is a water tank for temporarily retaining coagulation-treated water including aggregates. The retention tank 4 is connected to the sedimentation tank 5 downstream via a pipe 7a. In addition, the retention tank 4 is provided with a pH meter 8 that measures pH of the coagulation-treated water. It should be noted that the position of the pH meter 8 is not limited to the retention tank 4, and for example, the pH meter 8 may be provided in the raw water pipe 7 on the downstream side of the coagulant injection unit 2.

[0024] The sedimentation tank 5 causes coagulation-treated water flowing in from the retention tank 4 to settle and undergo solid-liquid separation into solid components and supernatant liquid. The supernatant liquid is supplied to the membrane filtration tank 6 in the downstream stage via a pipe 7b. It should be noted that solid components concentrated in the sedimentation tank 5 are transferred to a sludge treatment facility (not shown) external to the system.

[0025] The membrane filtration tank 6 has a filtration membrane 9 that performs filtration treatment of coagulation-treated water that has been primary-treated in the sedimentation tank 5. In the membrane filtration tank 6, aggregates remaining in the coagulation-treated water are filtered by the filtration membrane 9, and filtrate from which the aggregates have been separated and removed is generated.

[0026] As examples of the above-described filtration membrane 9, ceramic membranes having silica, alumina, silicon carbide, or cordierite, and mixtures thereof as main components, organic membranes such as PVDF (polyvinylidene fluoride) and PTFE (polytetrafluoroethylene), and hybrid membranes of ceramic membranes and organic membranes can be applied. It should be noted that in the present embodiment, a case in which a ceramic membrane having alumina as the main component is applied as the filtration membrane 9 will be explained.

[0027] Here, materials of ceramic membranes and organic membranes applied to the filtration membrane 9 each have positive or negative charges in water. For example, a ceramic membrane having alumina as a main component has a membrane surface that is positively charged in water near neutrality or in water of pH 5 to 8. In addition, in the case of organic membranes such as PVDF, the membrane surface is usually negatively charged in water.

[0028] For example, with respect to a ceramic membrane having alumina as a main

component, when aggregates included in coagulation-treated water are strongly negatively charged, the aggregates are likely to adsorb to the surface of the membrane that is positively charged, and blocking of the filtration membrane 9 is likely to occur. When blocking of the filtration membrane 9 by aggregates becomes significant, the transmembrane pressure becomes high and causes membrane filtration failure.

[0029] In a case in which the material of the membrane is positively charged in water, if aggregates included in coagulation-treated water are positively charged, adsorption of the aggregates to the surface of the membrane decreases, and progression of blocking of the filtration membrane 9 becomes gradual. In addition, in the above-described case, even when aggregates included in coagulation-treated water are negatively charged, if the charge amount of the aggregates becomes small, adsorption to the surface of the membrane that is positively charged decreases. The magnitude of the charge amount of aggregates is indicated by the zeta potential. The larger the absolute value of the zeta potential of aggregates becomes, the greater the charge amount of the aggregates becomes, and conversely, the smaller the absolute value of the zeta potential of aggregates becomes, the smaller the charge amount of the aggregates becomes.

[0030] It should be noted that in the case of organic membranes such as PVDF, the membrane surface is normally negatively charged in water as described above. In a case in which the material of the membrane is negatively charged in water, when aggregates included in coagulation-treated water are negatively charged, or when the charge amount of the aggregates is reduced (that is, to reduce the absolute value of the zeta potential of the aggregates), adsorption of the aggregates to the surface of the membrane becomes difficult.

[0031] Although specific values are not particularly limited, from the viewpoint of

making aggregates difficult to adsorb to the surface of the membrane, in the case of ceramic membranes having alumina as a main component, it is preferable to adjust the zeta potential of aggregates to a positive side relative to −10 mV (more preferably −7 mV or higher).

[0032] In addition, in the case of a ceramic membrane having alumina as a main component, from the viewpoint of both making aggregates difficult to adsorb to the surface of the membrane and suppressing the injection amount of the coagulant, it is preferable to adjust so that the zeta potential of the aggregates falls within the negative-side region of the target range. As an example, in the case of a ceramic membrane having alumina as a main component, it is more preferable to adjust so that the zeta potential of the aggregates is -7 mV or higher and falls within a region near -7 mV (for example, a range of -7 mV or higher and -3 mV or lower).

[0033] The control apparatus 10 controls a coagulant injection rate of the coagulant injection unit 2 so that the zeta potential of the aggregates generated by coagulation treatment falls within a target range corresponding to the material of the membrane. The control apparatus 10 is, for example, a computer having a CPU (Central Processing Unit) 10a, a memory 10b, and a storage device 10c, and the control apparatus 10 is connected to the pH meter 8 and the coagulant injection unit 2. It should be noted that the CPU 10a and the memory 10b are examples of a control unit, and the memory 10b and the storage device 10c are examples of a storage unit.

[0034] The CPU 10a executes programs stored in the storage device 10c and controls each element connected to the control apparatus 10. The memory 10b functions as main memory, work area, and the like for the CPU 10a. The storage device 10c is configured by, for example, a hard disk or a solid state drive, and stores programs and various data necessary for execution of the programs. It should be noted

that the control apparatus 10 may be configured by a hardware circuit.

[0035] Here, the correspondence relationship between the zeta potential and pH value of aggregates in raw water differs according to the type of raw water and the state of the raw water at various times. Therefore, in the storage device 10c or the memory 10b of the present embodiment, data indicating the correspondence relationship between the zeta potential and pH value of aggregates when the coagulant injection rate is changed is held in advance with respect to the raw water to be processed. When the above-described correspondence relationship with respect to the raw water to be processed is known, the pH value when the zeta potential of the aggregates is within a target range corresponding to the material of the membrane (for example, when the zeta potential of the aggregates is on a positive side relative to -10 mV) can be set as a pH value of an adjustment target. Although the above-described data of the correspondence relationship is set before the start of operation of the filtration membrane system 1, the data may be updated as appropriate after the start of operation.

[0036] Data of the above-described correspondence relationship is generated by an operator by preparing a plurality of samples of coagulation-treated water having different coagulant injection rates, and measuring the zeta potential of the aggregates and the pH value of the coagulation-treated water for each sample. In the measurement of the zeta potential in each sample, for example, the zeta potential of aggregate particles having predetermined dimensions or smaller contained in the sample may be measured by electrophoretic method, and the zeta potential of the aggregates may be determined by the average value of these measurements. In addition, the pH value of each sample can be obtained by general pH measurement methods.

[0037] The control apparatus 10 of the present embodiment performs the following operation as an example. First, the control apparatus 10 monitors the current pH value

of the coagulation-treated water by acquiring the current pH value from the pH meter 8. The current pH value has a correlation with the zeta potential of aggregates in the coagulation-treated water.

[0038] Then, the control apparatus 10 instructs the coagulant injection unit 2 to change the coagulant injection rate so that the pH value measured by the pH meter 8 falls within the range of adjustment target pH values in which the zeta potential of the aggregates is within an appropriate range. Accordingly, the coagulant injection rate of the coagulant injection unit 2 is feedback-controlled in accordance with the pH value of the raw water after coagulant injection.

[0039] For example, in a case in which the absolute value of the zeta potential of the aggregates estimated from the current pH value is large, the control apparatus 10 increases the coagulant injection rate so that the pH value is decreased and the absolute value of the zeta potential of the aggregates becomes small. In contrast, in a case in which the pH value does not fall within the range of the adjustment target because the amount of coagulant injected has become excessive, the control apparatus 10 decreases the coagulant injection rate under the condition that the pH value is within the range of the adjustment target. It should be noted that the amount of change of the coagulant injection rate may be set automatically by the control apparatus 10 based on a program, or may be set based on input by an operator.

[0040] FIG. 5(a) is a flow diagram showing an example of a control method for the filtration membrane system 1 of the first embodiment. In a preparation step (S1), raw water is collected, a plurality of samples of coagulation-treated water in which the coagulant injection rate has been changed are prepared, and the zeta potential of the aggregates and the pH value of the coagulation-treated water are measured for each of the samples. Accordingly, data of the correspondence relationship between the zeta

potential of the aggregates and the pH value when the coagulant injection rate is changed is generated with respect to the raw water to be processed. The above-described data of the correspondence relationship is stored in the storage device 10c or the memory 10b of the control apparatus 10, and is read out by the CPU 10a.

[0041] In a coagulant injection step (S2), the coagulant injection unit 2 injects a coagulant into the raw water of the raw water pipe 7 at the set coagulant injection rate. Accordingly, aggregates are generated in the coagulation-treated water. In addition, the coagulation-treated water after coagulant injection flows into the membrane filtration tank 6 via the retention tank 4 and the sedimentation tank 5, and is filtered by the filtration membrane 9.

[0042] In contrast, in a pH measurement step (S3), the pH meter 8 measures the pH value of coagulation-treated water after coagulant injection. In an injection rate adjustment step (S4), the control apparatus 10 adjusts the coagulant injection rate so that the pH value falls within the range of adjustment target pH values in which the zeta potential of the aggregates is within an appropriate range, based on the data of the above-described correspondence relationship acquired in the preparation step (S1) and the pH value measured in a pH measurement step (S3). Thereafter, returning to step S2, the above-described processing is repeated. It should be noted that a coagulant injection step (S2), a pH measurement step (S3), and an injection rate adjustment step (S4) are examples of control steps.

[0043] As described above, in the coagulant injection unit 2 of the first embodiment, the coagulant is injected into the raw water so that the absolute value of the zeta potential of the aggregates becomes small, and the charge amount of the aggregates becomes small on the downstream side of the coagulant injection unit 2. As a result, even when the aggregates remaining in the coagulation-treated water flow

into the membrane filtration tank 6, blocking of the filtration membrane 9 is unlikely to occur because the adsorptivity of the aggregates to the surface of the filtration membrane 9 is low.

[0044] In addition, in the present embodiment, the pH value of the coagulation-treated water after coagulant injection is measured and monitored using the pH meter 8, and the coagulant injection rate is adjusted so that the pH value falls within the range of adjustment target pH values in which the zeta potential of the aggregates is within an appropriate range. Although it is difficult to monitor the zeta potential of the aggregates continuously, in the present embodiment, by controlling the coagulant injection rate using the pH value, the zeta potential of the aggregates, which is difficult to monitor continuously, can be appropriately controlled.

(Second Embodiment)

[0045] FIG. 2 is a diagram showing a configuration example of a filtration membrane system 1A of a second embodiment. It should be noted that, in the following explanation of the embodiment, elements common to the first embodiment are denoted by the same reference numerals, and redundant explanations are appropriately omitted.

[0046] The filtration membrane system 1A of the second embodiment is a modification example of the first embodiment, and corresponds to a configuration in which the retention tank 4 and the sedimentation tank 5 are omitted from the filtration membrane system 1 of the first embodiment. In the second embodiment, the downstream side of the raw water pipe 7 is connected to the membrane filtration tank 6, and the coagulant injection unit 2 is connected to the raw water pipe 7 upstream of the membrane filtration tank 6. In addition, the membrane filtration tank 6 is provided with the pH meter 8 that measures the pH of the coagulation-treated water. It should be

noted that the position of the pH meter 8 is not limited to the membrane filtration tank 6, and, for example, the pH meter 8 may be provided in the raw water pipe 7 on the downstream side of the coagulant injection unit 2.

[0047] The control apparatus 10 of the second embodiment, similarly to the first embodiment, instructs the coagulant injection unit 2 to change the coagulant injection rate so that the pH value measured by the pH meter 8 falls within the range of adjustment target pH values in which the zeta potential of the aggregates is within an appropriate range. Also, in the configuration of the second embodiment, effects similar to those of the above-described first embodiment can be obtained.

(Third Embodiment)

[0048] FIG. 3 is a diagram showing a configuration example of a filtration membrane system 1B of a third embodiment. The filtration membrane system 1B of the third embodiment is a configuration example in which injection of a pH adjusting agent and injection of a coagulant are used in combination with respect to the raw water.

[0049] The filtration membrane system 1B of the third embodiment comprises a pH adjusting agent injection unit 3, the coagulant injection unit 2, the retention tank 4, the sedimentation tank 5, the membrane filtration tank 6, and the control apparatus 10. The downstream side of the raw water pipe 7 of the third embodiment is connected to the retention tank 4. In addition, the pH adjusting agent injection unit 3 and the coagulant injection unit 2 are respectively connected to the raw water pipe 7. In the third embodiment, configurations of the coagulant injection unit 2, the retention tank 4, the sedimentation tank 5, and the membrane filtration tank 6 are similar to those of the first embodiment.

[0050] The pH adjusting agent injection unit 3 is disposed upstream of the coagulant injection unit 2, and injects the pH adjusting agent at a predetermined ratio

into the raw water flowing through the raw water pipe 7. Examples of the pH adjusting agent include acids such as hydrochloric acid and sulfuric acid, or alkalis such as caustic soda and lime. However, types of acids and alkalis of the pH adjusting agent are not limited to those described above.

[0051] As an example, in a case in which the material of the membrane is positively charged in water, the zeta potential of aggregates generated in a coagulation process can be adjusted to the positive side by adjusting the pH of the raw water toward the acidic side by using the pH adjusting agent. Accordingly, adsorption of aggregates to the membrane surface can also be reduced by adjustment of the pH of the raw water.

[0052] The configuration and operations of the control apparatus 10 of the third embodiment are similar to those of the first embodiment. However, in the third embodiment, with respect to the raw water to be processed, data indicating the correspondence relationship between the zeta potential of the aggregates and pH values when coagulant injection amounts are made different is generated by preparing a plurality of samples of coagulation-treated water in which the pH adjusting agent is injected at a predetermined ratio and the coagulant injection rate is varied, and measuring the zeta potential of the aggregates and pH values of the coagulation-treated water for each sample.

[0053] FIG. 5(b) is a flow diagram showing an example of a control method for the filtration membrane system 1B of the third embodiment. In a preparation step (S11), the raw water is collected, and a plurality of samples of the coagulation-treated water are prepared in which the pH adjusting agent is injected at a predetermined ratio and the coagulant injection rate is changed. The zeta potential of the aggregates and the pH value of the coagulation-treated water are measured for each of the samples. Accordingly, data of correspondence relationships between the zeta potential of the

aggregates and the pH value when the coagulant injection rate is changed is generated for the raw water to be processed. The generated data of the correspondence relationships is stored in the storage device 10c or the memory 10b of the control apparatus 10, and is read out by the CPU 10a.

[0054] In the pH adjusting agent injection step (S12), the pH adjusting agent injection unit 3 injects the pH adjusting agent at a predetermined ratio into the raw water of the raw water pipe 7. In a coagulant injection step (S13), the coagulant injection unit 2 injects the coagulant at the set injection rate into the raw water of the raw water pipe 7. Accordingly, turbid matter, colloids, and dissolved substances included in the raw water react with the coagulant, and aggregates are generated in the coagulation-treated water. In addition, the coagulation-treated water after coagulant injection flows into the membrane filtration tank 6 via the retention tank 4 and the sedimentation tank 5, and filtration treatment is performed by the filtration membrane 9.

[0055] In contrast, in a pH measurement step (S14), the pH meter 8 measures the pH value of the coagulation-treated water after coagulant injection. In an injection rate adjustment step (S15), the control apparatus 10 adjusts the coagulant injection rate so that the pH value falls within a range of adjustment target pH values in which the zeta potential of the aggregates is within an appropriate range, based on the data of the above-described correspondence relationships acquired in the preparation step (S11) and the pH value measured in the pH measurement step (S14). Thereafter, returning to step S13, the above-described processing is repeated. It should be noted that the pH adjusting agent injection step (S12), the coagulant injection step (S13), the pH measurement step (S14), and the injection rate adjustment step (S15) are examples of control steps.

[0056] As described above, in the third embodiment, the coagulant and the pH

adjusting agent are used in combination, and the coagulant injection rate is adjusted in the coagulant injection unit 2 so that the pH value falls within a range of adjustment target pH values in which the zeta potential of the aggregates is within an appropriate range. In the third embodiment as well, effects similar to those of the first embodiment can be obtained. Furthermore, in the third embodiment, by using the coagulant and the pH adjusting agent in combination, there is an advantage that the usage amount of the coagulant can be suppressed compared to a case in which the coagulant is used alone as in the first embodiment.

[0057] It should be noted that, although in the third embodiment an example was explained in which the coagulant injection unit 2 injects the coagulant after the pH adjusting agent is injected at a predetermined ratio, the pH adjusting agent injection unit 3 may be configured so as to inject the pH adjusting agent at a predetermined ratio after the coagulant injection unit 2 has injected the coagulant.

(Fourth Embodiment)

[0058] FIG. 4 is a diagram showing a configuration example of a filtration membrane system of a fourth embodiment. A filtration membrane system 1C of the fourth embodiment is a configuration example in which injection of a pH adjusting agent and injection of a coagulant are used in combination with respect to the raw water, similarly to the third embodiment. In the fourth embodiment, injection of a coagulant is fixed at a predetermined ratio and the injection rate of a pH adjusting agent is adjusted, differing from the third embodiment in this respect.

[0059] The filtration membrane system 1C of the fourth embodiment comprises a coagulant injection unit 2, a pH adjusting agent injection unit 3, the retention tank 4, the sedimentation tank 5, the membrane filtration tank 6, and the control apparatus 10. The downstream side of the raw water pipe 7 of the fourth embodiment is connected to

the retention tank 4. In addition, the pH adjusting agent injection unit 3 and the coagulant injection unit 2 are respectively connected to the raw water pipe 7. In the fourth embodiment, each configuration of the retention tank 4, the sedimentation tank 5, and the membrane filtration tank 6 is the same as that of the first embodiment.

[0060] The coagulant injection unit 2 injects the coagulant at a predetermined ratio into the raw water flowing through the raw water pipe 7. The pH adjusting agent injection unit 3 is disposed downstream of the coagulant injection unit 2, and injects the pH adjusting agent into the raw water (coagulation-treated water) flowing through the raw water pipe 7. In addition, the control apparatus 10 of the fourth embodiment controls the injection rate of the pH adjusting agent of the pH adjusting agent injection unit 3 so that the zeta potential of aggregates generated in coagulation treatment falls within a target range.

[0061] FIG. 5 (c) is a flow diagram showing an example of a control method for the filtration membrane system 1C of the fourth embodiment. In a preparation step (S21), the raw water is collected, and a plurality of samples of coagulation-treated water are prepared in which the coagulant is injected at a predetermined ratio and the injection rate of the pH adjusting agent is changed, and the zeta potential of the aggregates and the pH value of the coagulation-treated water are measured for each of these samples. Accordingly, data of the correspondence relationship between the zeta potential of the aggregates and the pH value when the pH adjusting agent is changed is generated for the raw water to be processed. The generated data of the correspondence relationship is stored in the storage device 10c or the memory 10b of the control apparatus 10, and is read out by the CPU 10a.

[0062] In a coagulant injection step (S22), the coagulant injection unit 2 injects the coagulant at a predetermined ratio into the raw water of the raw water pipe 7.

Accordingly, aggregates are generated in the coagulation-treated water. In the pH adjusting agent injection step (S23), the pH adjusting agent injection unit 3 injects the pH adjusting agent at a set pH adjusting agent injection rate into the coagulation-treated water of the raw water pipe 7. In addition, the coagulation-treated water after injection of the coagulant and the pH adjusting agent flows into the membrane filtration tank 6 via the retention tank 4 and the sedimentation tank 5, and filtration treatment is performed by the filtration membrane 9.

[0063] In contrast, in a pH measurement step (S24), the pH meter 8 measures the pH value of the coagulation-treated water after injection of the coagulant and the pH adjusting agent. In the injection rate adjustment step (S25), the control apparatus 10 adjusts the pH adjusting agent injection rate so that the pH value falls within a range of adjustment target pH values in which the zeta potential of the aggregates is within an appropriate range, based on the above-described data of the correspondence relationship acquired in the preparation step (S21) and the pH value measured in the pH measurement step (S24). Thereafter, returning to step S23, the above-described processing is repeated. It should be noted that the coagulant injection step (S22), the pH adjusting agent injection step (S23), the pH measurement step (S24), and the injection rate adjustment step (S25) are examples of control steps.

[0064] As described above, in the fourth embodiment, the coagulant and the pH adjusting agent are used in combination, and the pH value of the coagulation-treated water is adjusted so that the absolute value of the zeta potential of the aggregates becomes small by controlling the injection amount of the pH adjusting agent. In the fourth embodiment as well, effects similar to those of the third embodiment can be obtained.

[0065] It should be noted that, although in the fourth embodiment an example was

explained in which the pH adjusting agent injection unit 3 injects the pH adjusting agent after the coagulant is injected at a predetermined ratio, the coagulant injection unit 2 may inject the coagulant at a predetermined ratio after the pH adjusting agent injection unit 3 has injected the pH adjusting agent.

(First Example)

[0066] Hereinafter, examples of the present invention will be explained. In the first example, when river water was used as the raw water and ferric chloride was applied as the coagulant, the coagulant injection rate was changed and the zeta potential of the aggregates contained in the supernatant of the coagulation-treated water and the pH of the coagulation-treated water were respectively measured. For measurement of the zeta potential, a zeta potential measuring apparatus using electrophoresis (Malvern, Zetasizer, Nano ZS) was used.

[0067] FIG. 6 is a graph showing the coagulant injection rate, the zeta potential of the aggregates, and the pH of the coagulation-treated water in the first example. The horizontal axis of FIG. 6 indicates the coagulant injection rate, the left vertical axis of FIG. 6 indicates the zeta potential, and the right vertical axis of FIG. 6 indicates the pH of the coagulation-treated water. In addition, the solid line of FIG. 6 shows changes in the zeta potential with respect to the coagulant injection rate, and the broken line of FIG. 6 shows changes in the pH of the coagulation-treated water with respect to the coagulant injection rate.

[0068] Normally, the aggregates contained in river water are negatively charged. Even in the case of the first example shown in FIG. 6, when the injection rate of the coagulant (ferric chloride) was zero, the zeta potential of the aggregates was -22 mV, and the aggregates were negatively charged. In the first example, the zeta potential of the aggregates rose to near zero as the injection amount of ferric chloride increased, and

finally the zeta potential turned positive. That is, from FIG. 6, it can be seen that as the injection rate of ferric chloride increases, the absolute value of the zeta potential becomes small, and the charge amount on the aggregate surface becomes small.

[0069] In addition, although the pH of the river water used as the raw water in the first example was 8.0, the pH decreased as the injection rate of ferric chloride increased, and the pH decreased to 5.0 when the injection rate was 60 mg/L. In the first example, when the injection rate of ferric chloride was 24 mg/L, the pH was 6.5, and the zeta potential of the aggregates under these conditions was -7 mV (Example 1 of FIG. 7 described later). When the injection rate of ferric chloride was 28 mg/L, the pH was 6.2, and the zeta potential of the aggregates under these conditions was -5 mV (Example 2 of FIG. 7 described later). Furthermore, when the injection rate of ferric chloride was 34 mg/L, the pH was 6.0, and the zeta potential of the aggregates under these conditions was -3 mV (Example 3 of FIG. 7 described later). From the graph of FIG. 6, it can be seen that by monitoring the pH, the coagulant injection rate can be controlled so that the zeta potential of the aggregates becomes a predetermined value.

[0070] In addition, in the first example, in order to evaluate the stability of membrane filtration in the membrane filtration process, the rate of increase of the transmembrane pressure during membrane filtration was measured. A membrane module incorporating a plurality of ceramic flat membranes was applied to the membrane filtration process of the first example. The membrane module had a structure in which the filtrate from each ceramic flat membrane was collected by a water collection pipe. The membrane module was immersed in a membrane separation tank, a filtration pump was connected to the water collection pipe through piping, and the membrane filtrate was obtained by suction by the filtration pump. The transmembrane pressure was calculated from values of a pressure gauge installed in the filtration piping,

and the rate of increase of the transmembrane pressure was obtained from changes thereof over time.

[0071] FIG. 7 is a diagram showing the zeta potential of the aggregates and the rate of increase of the transmembrane pressure of the filtration membrane when the pH of coagulation-treated water into which the coagulant has been injected is changed in the first example. In FIG. 7, in a case in which pH set values are set to 6.8 to 7.4 (Comparative Examples 1 to 3 of FIG. 7), the zeta potential of the aggregates falls within a range of -15 to -10 mV. In the cases of these Comparative Examples 1 to 3, the rate of increase of the transmembrane pressure is 20 to 30 kPa/d, and membrane blocking progressed at a rapid rate.

[0072] In contrast, in FIG. 7, in a case in which pH set values are set to 6.0 to 6.5 (Examples 1 to 3 of FIG. 7), the injection rates of ferric chloride are 24 to 34 mg/L, the zeta potential of the aggregates at this time becomes -3 to -7 mV, and the rate of increase of the transmembrane pressure becomes 1.2 to 2.0 kPa/d. In the cases of Examples 1 to 3, the transmembrane pressure increase rate can be reduced to one-tenth or less of Comparative Examples 1 to 3.

[0073] As described above, according to the first example, membrane blocking can be remarkably suppressed and stable membrane filtration can be realized by controlling the pH of the coagulation-treated water so that the zeta potential of the aggregates falls within a predetermined range by injection of the coagulant.

(Second Example)

[0074] The second example is an example in which pH adjustment by a pH adjusting agent and injection of a coagulant are used in combination, similarly to the above-described third embodiment. In the second example, in a case in which river water was used as raw water and sulfuric acid was applied as the pH adjusting agent and

ferric chloride was applied as the coagulant, coagulant injection rates were changed, and the zeta potential of aggregates contained in supernatant water of coagulation-treated water and the pH of the coagulation-treated water were respectively measured. Although the pH of the original river water was 8.0, in the second example, the pH of the raw water before injection of the coagulant was adjusted to 7.0 by pre-injection of sulfuric acid.

[0075] FIG. 8 is a graph showing the coagulant injection rates, the zeta potential of aggregates, and the pH of the coagulation-treated water in the second example. The interpretation of FIG. 8 is similar to that of FIG. 6.

[0076] In a case in which sulfuric acid is pre-injected as in the second example, when the injection rates of ferric chloride are 14 to 23 mg/L, the zeta potential of aggregates can be adjusted to -7 to -3 mV. It should be noted that the rate of increase of the transmembrane pressure in the above-described range becomes 1.2 to 2.0 kPa/d, and stable membrane filtration can be realized similarly to Examples 1 to 3 of the above-described FIG. 7.

[0077] When the second example and the above-described first example are compared, in the first example in which pH adjustment is not performed in addition to coagulant injection, the injection rates of ferric chloride were 24 to 34 mg/L, whereas in the second example, the injection rates of ferric chloride were 14 to 23 mg/L. That is, by using injection of the coagulant and pH adjustment by the pH adjusting agent in combination as in the second example, stable membrane filtration can be realized while suppressing injection rates of the coagulant to low levels.

(Third Example)

[0078] In the third example, in a case in which river water was used as raw water and aluminum sulfate was applied as the coagulant in place of ferric chloride, coagulant

injection rates were changed, and the zeta potential of aggregates contained in supernatant water of coagulation-treated water and the pH of the coagulation-treated water were respectively measured.

[0079] FIG. 9 is a graph showing the coagulant injection rates, the zeta potential of aggregates, and the pH of the coagulation-treated water in coagulation-treated water of the third example. The interpretation of FIG. 9 is similar to that of FIG. 6.

[0080] In the case of the first example in which ferric chloride was applied as the coagulant, when the coagulant injection rates were 24 to 34 mg/L, pH was 6.0 to 6.5, and the zeta potential of aggregates under these conditions became -3 to -7 mV. In contrast, as shown in FIG. 9, in the case of the third example in which aluminum sulfate was applied as the coagulant, when the coagulant injection rates were 80 to 120 mg/L, pH was 6.0 to 6.5, and the zeta potential of aggregates under these conditions was -3 to -7 mV. It should be noted that the rate of increase of the transmembrane pressure in the above-described range was 1.2 to 2.0 kPa/d, and stable membrane filtration could be realized similarly to Examples 1 to 3 of the above-described FIG. 7.

[0081] According to the third example, it can be understood that even in a case in which a coagulant different from the coagulant of the first example is applied, effects similar to the effects of the first example can be obtained.

[0082] The present invention is not limited to the above-described embodiments, and various improvements and design changes may be performed within a range that does not depart from the spirit of the present invention.

[0083] In the above-described embodiments, examples were explained in which the control apparatus 10 changes the injection rate of either the coagulant or the pH adjusting agent. However, the control apparatus 10 may perform control in which both the injection rate of the coagulant and the injection rate of the pH adjusting agent are

changed.

[0084] In addition, the embodiments disclosed herein are to be considered in all respects as illustrative and non-limiting ones. The scope of the present invention is indicated not by the above description but by the scope of claims, and it is intended that meanings equivalent to the scope of claims and all modifications within the scope are included.

REFERENCE SIGNS LIST

[0085]

1, 1A, 1B, 1C FILTRATION MEMBRANE SYSTEM

2 COAGULANT INJECTION UNIT

3 pH ADJUSTING AGENT INJECTION UNIT

4 RETENTION TANK

5 SEDIMENTATION TANK

6 MEMBRANE FILTRATION TANK

7 RAW WATER PIPE

7a, 7b PIPE

8 pH METER

9 FILTRATION MEMBRANE

10 CONTROL APPARATUS

10a CPU

10b MEMORY

10c STORAGE DEVICE

CLAIMS

1. A control method for a filtration membrane system comprising a coagulant injection unit configured to inject a coagulant into raw water, and a filtration membrane configured to obtain filtrate by filtration treatment of coagulation-treated water of the raw water containing aggregates formed by injection of the coagulant,

wherein the filtration membrane is an alumina-based ceramic membrane that is positively charged in the coagulation-treated water,

the control method comprising a control step of controlling injection rates of at least one of the coagulant and a pH adjusting agent so that the zeta potential of the aggregates falls within a target range corresponding to the material of the filtration membrane, as preprocessing before the filtration treatment by the filtration membrane, and

wherein in the control step, the injection rate of at least one of the coagulant and the pH adjusting agent is controlled so that the zeta potential of the aggregates is -7 mV or higher and the zeta potential falls within a negative-side region of the target range.

2. The control method for a filtration membrane system according to claim 1, further comprising a preparation step of acquiring a correspondence relationship between the pH values of the coagulation-treated water and the zeta potential of the aggregates,

wherein in the control step, the pH values of the coagulation-treated water are monitored, and injection rates of at least one of the coagulant and the pH adjusting agent are controlled so that the monitored pH values of the coagulation-treated water fall within a pH value range corresponding to the target range, based on the correspondence relationship.

3. The control method for a filtration membrane system according to claim 1 or claim 2, wherein in the control step, the pH adjusting agent is injected into the raw water at a predetermined ratio, and the injection rate of the coagulant is controlled so that the zeta potential of the aggregates falls within a target range corresponding to the material of the filtration membrane.

4. The control method for a filtration membrane system according to claim 1 or claim 2, wherein in the control step, the coagulant is injected into the raw water at a predetermined ratio, and the injection rate of the pH adjusting agent is controlled so that the zeta potential of the aggregates falls within a target range corresponding to the material of the filtration membrane.

5. The control method for a filtration membrane system according to claim 1 or claim 2, wherein the filtration membrane system further comprises a sedimentation tank configured to perform solid-liquid separation of the aggregates upstream of the filtration membrane, and the filtration membrane is configured to perform filtration treatment of the coagulation-treated water after the solid-liquid separation.

6. A control apparatus for a filtration membrane system comprising a coagulant injection unit configured to inject a coagulant into raw water, and a filtration membrane configured to obtain filtrate by filtration treatment of coagulation-treated water of the raw water containing aggregates formed by injection of the coagulant,

wherein the filtration membrane is an alumina-based ceramic membrane that is positively charged in the coagulation-treated water,

the control apparatus comprising a control unit configured to adjust injection rates

of at least one of the coagulant and a pH adjusting agent so that the zeta potential of the aggregates falls within a target range corresponding to the material of the filtration membrane, upstream of filtration treatment by the filtration membrane, and

wherein the control unit controls the injection rate of at least one of the coagulant and the pH adjusting agent so that the zeta potential of the aggregates is -7 mV or higher and the zeta potential falls within a negative-side region of the target range.

7. The control apparatus according to claim 6, further comprising a storage unit configured to hold data of correspondence relationship between the pH values of the coagulation-treated water and the zeta potential of the aggregates, wherein the control unit acquires the pH values of the coagulation-treated water, and controls the injection rate of at least one of the coagulant and the pH adjusting agent so that the pH values of the coagulation-treated water fall within a pH value range corresponding to the target range, based on the correspondence relationship.

8. A filtration membrane system comprising:

a coagulant injection unit configured to inject a coagulant into raw water,

a filtration membrane configured to obtain filtrate by filtration treatment of coagulation-treated water of the raw water containing aggregates formed by injection of the coagulant, and

a control apparatus according to claim 6 or claim 7.