

DESCRIPTION

TREATMENT SYSTEM AND TREATMENT METHOD FOR SILICA-CONTAINING WATER

TECHNICAL FIELD

[0001]

The present invention relates to a silica-containing water treatment system and method for treating silica contained in silica-containing water.

BACKGROUND

[0002]

Recovery and reuse of silica-containing water has the problem of scale formation in piping, a reverse osmosis membrane (RO) device at a subsequent stage, and so on, which makes it difficult to improve the recovery rate of the silica-containing water and to perform stable operation in some cases. Thus, it is required to reduce the amount of silica in silica-containing water.

[0003]

A studied method for reducing the amount of silica in silica-containing water includes a method of using a magnesium salt.

[0004]

For example, Patent Literature 1 discloses a method of reducing the amount of silica, the method including adding a magnesium salt to silica-containing water, adsorbing silica on a generated $\text{Mg}(\text{OH})_2$, and then, adding an iron salt to flocculate the silica, and performing solid-liquid separation, in which a high silica removal rate is achieved by warming the silica-containing water to 50°C or higher. However, since the

method of Patent Literature 1 requires a heat source for the warming, there is a problem that treatment costs increase.

[0005]

Non Patent Literature 1 describes a method of reducing the amount of silica, the method including: adding a mixture, obtained by adding a sulfuric acid to magnesium slurry containing MgO and the like, to silica-containing water; and separating a solid content, in which a silica recovery rate improved compared with a case of not adding the sulfuric acid to the magnesium slurry. However, in the method of Non Patent Literature 1, approximately 20 mg/L of silica remains in treated water. When considering risk of silica scale, in a case of providing a reverse osmosis membrane device at a subsequent stage, it is difficult to increase a recovery rate of the reverse osmosis membrane device,

CITATION LIST

PATENT LITERATURE

[0006]

Patent Literature 1: JP 2014-168742 A

NON PATENT LITERATURE

[0007]

Non Patent Literature 1: Isabel Latour, Ruben Miranda, Angeles Blanco, "Silica removal with sparingly soluble magnesium compounds. Part I", Separation and Purification Technology, 138 (2014), pp. 210-218

SUMMARY

[0008]

An object of the present invention is to provide a silica-containing water treatment system and method capable of efficiently treating silica-containing water.

[0009]

According to the present invention, there is provided a silica-containing water treatment system including: a magnesium dissolving unit in which a magnesium salt and an acid are mixed with each other and reacted at a pH of 7 or lower to prepare a magnesium-containing liquid; and a magnesium reaction unit in which a mixed liquid obtained by mixing silica-containing water and the magnesium-containing liquid is reacted at a pH in the range of 10 to 12.

[0010]

The silica-containing water treatment system preferably includes: a magnesium dissolving tank as the magnesium dissolving unit in which the magnesium salt and the acid are mixed with each other and reacted at a pH of 7 or lower to prepare a magnesium-containing liquid; and a magnesium reaction tank as the magnesium reaction unit in which the mixed liquid obtained by mixing the silica-containing water and the magnesium-containing liquid is reacted at a pH in the range of 10 to 12.

[0011]

The silica-containing water treatment system preferably includes: a magnesium dissolving tank as the magnesium dissolving unit in which the magnesium salt and the acid are mixed in silica-containing water and reacted at a pH of 7 or lower to prepare the mixed liquid including a mixture of the magnesium-containing liquid and the silica-containing water; and a magnesium reaction tank as the magnesium reaction unit in which the mixed liquid is reacted at a pH in the range of 10 to 12.

[0012]

The silica-containing water treatment system preferably includes a removing unit for separating and removing an insolubilized substance obtained by a reaction performed by the magnesium reaction unit, at a stage subsequent to the magnesium reaction unit.

[0013]

In the silica-containing water treatment system, the removing unit preferably includes: a flocculation unit for flocculating the insolubilized substance using a

flocculating agent; and a solid-liquid separating unit for solid-liquid separating the flocculated substance, at a stage subsequent to the flocculation unit.

[0014]

In the silica-containing water treatment system, the flocculating agent is preferably at least one of an iron-based inorganic flocculating agent and a cationic polymer flocculating agent.

[0015]

In addition, according to the present invention, there is provided a silica-containing water treatment method including: a magnesium dissolving process in which a magnesium salt and an acid are mixed with each other and reacted at a pH of 7 or lower to prepare a magnesium-containing liquid; and a magnesium reaction process in which a mixed liquid obtained by mixing silica-containing water and the magnesium-containing liquid is reacted at a pH in the range of 10 to 12.

[0016]

In the magnesium dissolving process of the silica-containing water treatment method, the magnesium salt and the acid are preferably mixed with each other and reacted at a pH of 7 or lower to prepare the magnesium-containing liquid, and in the magnesium reaction process, the mixed liquid obtained by mixing the silica-containing water and the magnesium-containing liquid is preferably reacted at a pH in the range of 10 to 12.

[0017]

In the magnesium dissolving process of the silica-containing water treatment method, the magnesium salt and the acid are preferably mixed in silica-containing water and reacted at a pH of 7 or lower to prepare the mixed liquid including a mixture of the magnesium-containing liquid and the silica-containing water, and in the magnesium reaction process, the mixed liquid is preferably reacted at a pH in the range of 10 to 12.

[0018]

The silica-containing water treatment method preferably further includes: a removing process of separating and removing an insolubilized substance obtained by a reaction performed in the magnesium reaction process, at a stage subsequent to the magnesium reaction process.

[0019]

In the silica-containing water treatment method, the removing process preferably includes a flocculation process of flocculating the insolubilized substance using a flocculating agent and a solid-liquid separating process of solid-liquid separating the flocculated substance, at a stage subsequent to the flocculation process.

[0020]

In the silica-containing water treatment method, the flocculating agent is preferably at least one of an iron-based inorganic flocculating agent and a cationic polymer flocculating agent.

[0021]

According to the present invention, silica-containing water can be efficiently treated.

BRIEF DESCRIPTION OF DRAWINGS

[0022]

FIG. 1 is a schematic configuration diagram illustrating an example of a silica-containing water treatment system according to an embodiment of the present invention.

FIG. 2 is a schematic configuration diagram illustrating another example of the silica-containing water treatment system according to the embodiment of the present invention.

FIG. 3 is a schematic configuration diagram illustrating still another example of the silica-containing water treatment system according to the embodiment of the present invention.

FIG. 4 is a graph illustrating a silica concentration (mg/L) of flocculation and settlement-treated water and a silica removal rate (%) with respect to a pH of a Mg dissolving tank, in Example.

FIG. 5 is a graph illustrating a silica removal rate (%) with respect to an added amount (mg/L) of an Mg salt, in Example and Comparative Example.

DESCRIPTION OF EMBODIMENTS

[0023]

An embodiment of the present invention will be described below. The present embodiment is an example of implementing the present invention, and the present invention is not limited to the present embodiment.

[0024]

In a silica-containing water treatment method and a silica-containing water treatment system according to the embodiment of the present invention, a magnesium salt and an acid are mixed with each other and reacted at a pH of 7 or lower to prepare a magnesium-containing liquid (a magnesium dissolving process), and a mixed liquid, in which silica-containing water and the obtained magnesium-containing liquid are mixed with each other, is reacted at a pH in the range of 10 to 12 (a magnesium reaction process). After the magnesium reaction process, an insolubilized substance obtained by a reaction performed in the magnesium reaction process is separated and removed, as needed (a removing process).

[0025]

An example of a treatment system including a magnesium dissolving tank for preparing the magnesium-containing liquid and a magnesium reaction tank for reacting the mixed liquid in which silica-containing water and the obtained magnesium-containing liquid are mixed with each other will be illustrated below. However, the treatment system is not limited to the following configuration. As an example of a treatment system to

which the silica-containing water treatment method according to the present embodiment is adopted, System Example 1 (FIG. 1) in which the magnesium dissolving tank is separated from a flow of obtaining treated water from the silica-containing water via the magnesium reaction tank, and System Example 2 (FIG. 2) of obtaining the treated water from the silica-containing water via the magnesium dissolving tank and the magnesium reaction tank which are disposed in series. are mentioned below, and configurations thereof will be described.

[0026]

[System Example 1]

The silica-containing water treatment system 1 illustrated in FIG. 1 includes a magnesium dissolving tank 10 in which the magnesium salt and the acid are mixed with each other and reacted at a pH of 7 or lower to prepare a magnesium-containing liquid, and a magnesium reaction tank 12 for reacting the mixed liquid, which is obtained by mixing the silica-containing water and the magnesium-containing liquid with each other, at a pH in the range of 10 to 12. The silica-containing water treatment system 1 is a system example in which the magnesium dissolving tank 10 is separated from a flow of obtaining the treated water from the silica-containing water via the magnesium reaction tank 12.

[0027]

A silica-containing water pipe 18 is connected to a silica-containing water inlet of the magnesium reaction tank 12, and a treated water pipe 20 is connected to the treated water outlet thereof. An outlet of the magnesium dissolving tank 10 and a magnesium-containing liquid inlet of the magnesium reaction tank 12 are connected by a magnesium-containing liquid pipe 26. Stirring devices 14 and 16 including a stirring blade are installed in the magnesium dissolving tank 10 and the magnesium reaction tank 12, as a stirring unit, respectively. An acid addition pipe 22 and a magnesium salt addition pipe

24 are connected to the magnesium dissolving tank 10. A pH adjuster addition pipe 28 is connected to the magnesium reaction tank 12.

[0028]

Operations of the silica-containing water treatment method and the silica-containing water treatment system 1 according to the present embodiment will be described.

[0029]

An acid is added to the magnesium dissolving tank 10 through the acid addition pipe 22, for example, water slurry of a magnesium salt is added thereto through the magnesium salt addition pipe 24. These are stirred by the stirring device 14, and the magnesium salt and the acid are mixed and reacted at a pH of 7 or lower to prepare a magnesium-containing liquid (a magnesium dissolving process). A solid magnesium salt may be added as it is to the magnesium dissolving tank 10 to be mixed with the acid.

[0030]

On the other hand, the silica-containing water that contains silica is supplied to the magnesium reaction tank 12 through the silica-containing water pipe 18. In the magnesium reaction tank 12, the magnesium-containing liquid that is obtained in the magnesium dissolving process and contains the magnesium salt and the acid is added to the silica-containing water through the magnesium-containing liquid pipe 26 and stirred by the stirring device 16 and mixed. In addition, in the magnesium reaction tank 12, a pH adjuster is added to the magnesium-containing liquid through the pH adjuster addition pipe 28 and reacted at a pH in the range of 10 to 12, and the silica is insolubilized (a magnesium reaction process). The reaction liquid is discharged as treated water through the treated water pipe 20. Alternatively, after the magnesium reaction process, the reacted liquid may be subjected to a process in which an insolubilized substance obtained by a reaction performed in the magnesium reaction process is separated and removed by a removing unit (not illustrated) as needed (a removing process).

[0031]

In the silica-containing water treatment system 1, the magnesium dissolving tank 10, the stirring device 14, and the like, function as the magnesium dissolving unit in which a magnesium salt and an acid are mixed with each other and reacted at a pH of 7 or lower to prepare a magnesium-containing liquid, and the magnesium reaction tank 12, the stirring device 16, and the like function as the magnesium reaction unit for reacting a mixed liquid, in which silica-containing water and the magnesium-containing liquid are mixed with each other, at a pH in the range of 10 to 12.

[0032]

The present inventors have found that silica-containing water can be efficiently treated by reacting an acid and a magnesium salt at a pH of 7 or lower to form a magnesium-containing liquid and subjecting a mixed liquid obtained by mixing the resulting magnesium-containing liquid and the silica-containing water to a reaction at a pH of 10 to 12. The present inventors have also found that the silica removal rate can be significantly improved by separating and removing the insolubilized silica at a stage subsequent to the magnesium reaction tank 12 (the removing process).

[0033]

Accordingly, in a case where treated water is recovered and reused using a reverse osmotic membrane device or the like at a stage subsequent to the silica-containing water treatment system 1, treated water from which the silica was largely removed is obtained. Therefore, silica scale formation can be suppressed and a recovery rate can be improved.

[0034]

[System Example 2]

A silica-containing water treatment system 3 illustrated in FIG. 2 includes a magnesium dissolving tank 30 in which a magnesium salt and an acid are mixed in silica-containing water and reacted at a pH of 7 or lower to prepare a mixed liquid in which magnesium-containing liquid and silica-containing water are mixed with each other, and

a magnesium reaction tank 32 for reacting the mixed liquid at a pH in the range of 10 to 12. The silica-containing water treatment system 3 is a system example of obtaining the treated water from the silica-containing water via the magnesium dissolving tank 30 and the magnesium reaction tank 32 which are disposed in series.

[0035]

A silica-containing water pipe 38 is connected to a silica-containing water inlet of the magnesium dissolving tank 30. An outlet of the magnesium dissolving tank 30 and an inlet of the magnesium reaction tank 32 are connected by a magnesium-containing liquid pipe 40. A treated water pipe 42 is connected to an outlet of the magnesium reaction tank 32. Stirring devices 34 and 36 including a stirring blade are installed in the magnesium dissolving tank 30 and the magnesium reaction tank 32, as a stirring unit, respectively. An acid addition pipe 44 and a magnesium salt addition pipe 46 are connected to the magnesium dissolving tank 30. A pH adjuster addition pipe 48 is connected to the magnesium reaction tank 32.

[0036]

Operations of the silica-containing water treatment method and the silica-containing water treatment system 3 according to the present embodiment will be described.

[0037]

The silica-containing water that contains silica is supplied to the magnesium dissolving tank 30 through the silica-containing water pipe 38. In the magnesium dissolving tank 30, the acid is added to the silica-containing water through the acid addition pipe 44, and for example, water slurry of the magnesium salt is added thereto through the magnesium salt addition pipe 46. The magnesium salt, the acid, and the silica-containing water are mixed with each other by stirring of the stirring device 34, and reacted at a pH of 7 or lower to prepare a mixed liquid in which the magnesium-containing liquid and the silica-containing water are mixed with each other (a magnesium

dissolving process). A solid magnesium salt may be added as it is to the magnesium dissolving tank 10 to be mixed with the acid.

[0038]

The mixed liquid which is obtained in the magnesium dissolving process, and in which the magnesium-containing liquid containing the magnesium salt and the acid and silica-containing water are mixed each other, is supplied to magnesium reaction tank 32 through the magnesium-containing liquid pipe 40, and stirred by the stirring device 36. In addition, in the magnesium reaction tank 32, a pH adjuster is added to the mixed liquid through the pH adjuster addition pipe 48 and reacted at a pH in the range of 10 to 12, and the silica is insolubilized (a magnesium reaction process). The reaction liquid is discharged as treated water through the treated water pipe 42. Alternatively, after the magnesium reaction process, the reacted liquid may be subjected to a process in which an insolubilized substance obtained by a reaction performed in the magnesium reaction process is separated and removed by a removing unit (not illustrated) as needed (a removing process).

[0039]

In the silica-containing water treatment system 3, the magnesium dissolving tank 30, the stirring device 34, and the like function as the magnesium dissolving unit in which a magnesium salt and an acid are mixed with each other and reacted at a pH of 7 or lower to prepare a magnesium-containing liquid, and the magnesium reaction tank 32, the stirring device 36, and the like function as the magnesium reaction unit for reacting a mixed liquid, in which silica-containing water and the magnesium-containing liquid are mixed with each other, at a pH in the range of 10 to 12.

[0040]

In a case of using the silica-containing water treatment system 1 illustrated in FIG. 1, since the magnesium salt and the acid are directly mixed with each other in the magnesium dissolving tank 10, the time for dissolving the magnesium salt can be

shortened, and a volume of the magnesium dissolving tank can be reduced. In addition, the magnesium dissolving process can be set as a batch process. Further, even in a case where a silica concentration in the silica-containing water to be treated is changed, influence on the treatment can be reduced.

[0041]

The silica-containing water treatment system 3 illustrated in FIG. 2 is an effective system in a case where the silica-containing water is acidic. In addition, since the silica in the silica-containing water and dissolved magnesium flow into the magnesium reaction tank 32 in a state of coexisting, reactivity between the silica and the magnesium can be high, and a silica removal rate higher than that of the treatment system 1 can be obtained.

[0042]

The concentration of the silica in the silica-containing water to be treated is, for example, in the range of 10 mg/L to 500 mg/L.

[0043]

The silica-containing water to be treated is not particularly limited, as long as it is water that contains silica, and examples thereof include silica-containing water generated from a semiconductor manufacturing factory and silica-containing water generated from a power plant.

[0044]

The magnesium salt is not particularly limited as long as it is a magnesium salt or a hydrate thereof such as magnesium oxide (MgO), magnesium hydroxide ($\text{Mg}(\text{OH})_2$), or magnesium chloride ($\text{MgCl}_2 \cdot 6\text{H}_2\text{O}$), but the magnesium hydroxide ($\text{Mg}(\text{OH})_2$) is preferable from the viewpoint of chemical costs and the like. As the magnesium salt, a magnesium-containing mineral such as dolomite typified by a chemical formula of $\text{CaMg}(\text{CO}_3)_2$ may be used. In addition, the magnesium salt is preferably used as slurry of a solvent such as water, from the viewpoint of handling property and the like.

[0045]

The acid is not particularly limited, and an inorganic acid such as hydrochloric acid and sulfuric acid may be used. As the acid, an organic acid such as oxalic acid and citric acid may be added. However, since a chelate reaction of an organic acid may occur with magnesium depending on raw water, the removal rate of silica may be lowered. Therefore, caution is required.

[0046]

The added amount of the magnesium salt is preferably in the range of 0.1 to 10 times and more preferably in the range of 0.5 to 5 times a weight concentration of the silica in the silica-containing water, in terms of a magnesium concentration. When the added amount of the magnesium salt is less than 0.1 times the weight concentration of the silica in the silica-containing water, insolubilization reaction of the silica may be insufficient in some cases. When the added amount of the magnesium salt is more than 10 times the weight concentration of the silica in the silica-containing water, a sludge generation amount may become excessive in some cases.

[0047]

The pH in the magnesium dissolving process may be 7 or lower, and is preferably in the range of 4 to 7, and more preferably in the range of 4 to 6. When the pH in the magnesium dissolving process is higher than 7, dissolving of the magnesium salt may be insufficient. When the pH is lower than 4, since the silica removal rate hardly rises, acid injection costs may be wasted in some cases. However, when lowering the pH, it is possible to shorten the reaction time of the magnesium dissolving process.

[0048]

The temperature in the magnesium dissolving process is not particularly limited as long as magnesium can be dissolved, and is, for example, in the range of 1°C or higher and lower than 50°C, and more preferably in the range of 10°C or higher and lower than 50°C. When the temperature in the magnesium dissolving process is lower than 1°C, the dissolving of the magnesium salt may be insufficient in some cases. When the

temperature in the magnesium dissolving process is 50°C or higher, treatment costs may increase in some cases.

[0049]

The reaction time in the magnesium dissolving process is not particularly limited as long as magnesium can be dissolved, and is, for example, in the range of 1 minute to 60 minutes, and more preferably in the range of 5 minutes to 30 minutes. When the reaction time in the magnesium dissolving process is shorter than 1 minute, the dissolving of the magnesium salt may be insufficient in some cases. When the reaction time in the magnesium dissolving process is longer than 60 minutes, the reaction tank may become excessive in some cases. As described above, the reaction time can be shortened by lowering the pH in the magnesium dissolving process.

[0050]

As the pH adjuster, alkali such as sodium hydroxide and calcium hydroxide may be used, and as needed, an inorganic acid such as hydrochloric acid and sulfuric acid may also be used.

[0051]

The pH in the magnesium reaction process may be within a pH range of 10 to 12, and is preferably in the range of 10.5 to 11.5, and more preferably in the range of 11 to 11.5. When the pH in the magnesium reaction process is lower than 10 or higher than 12, the silica removal rate is lowered.

[0052]

The temperature in the magnesium reaction process is not particularly limited as long as it is a temperature at which insolubilization reaction of the silica proceeds, and is, for example, in the range of 1°C or higher and lower than 50°C, and more preferably in the range of 10°C or higher and lower than 50°C. When the temperature in the magnesium reaction process is lower than 1°C, the insolubilization reaction of the silica

may be insufficient in some cases. When the temperature in the magnesium reaction process is 50°C or higher, treatment costs may increase in some cases.

[0053]

The reaction time in the magnesium reaction process is not particularly limited as long as the insolubilization reaction of the silica can proceed. For example, the reaction time is in the range of 1 minute to 60 minutes, and more preferably in the range of 5 minutes to 30 minutes. When the reaction time in the magnesium reaction process is shorter than 1 minute, the insolubilization reaction of the silica may be insufficient in some cases. When the reaction time in the magnesium reaction process is longer than 60 minutes, the reaction tank may become excessive in some cases.

[0054]

The method for use in separating and removing silica may be, for example, a silica reduction method such as a flocculation and settling method, a pressurized floatation method, a sand filtration method, a membrane filtration method (for example, membrane filtration using a microfiltration membrane (MF membrane), ultrafiltration membrane (UF membrane), and the like), and the flocculation and settling method is preferable from the viewpoint of the sludge generation amount and the like.

[0055]

At a stage subsequent to the silica-containing water treatment system 1 or 3, the insolubilized silica may be separated and removed, and then a reverse osmosis membrane (RO membrane) treatment, a decarbonation treatment, an ion exchange treatment, a distillation treatment, or the like may be further performed. At the stage subsequent to the silica-containing water treatment system 1 or 3, the silica can be separated and removed at a high removal rate. Therefore, even when the resulting treated water is subjected to these treatments at a later stage, the risk of scale formation will be low.

[0056]

[System Example 3]

FIG. 3 shows a schematic configuration of an example of a silica-containing water treatment system in a case where the separating and removing of the insolubilized silica is performed by the flocculation and settling method at a stage subsequent to the magnesium reaction tank.

[0057]

A silica-containing water treatment system 5 illustrated in FIG. 3 is an example of a configuration in a case where a flocculation and settling treatment is performed at a stage subsequent to the magnesium reaction tank 32 of the silica-containing water treatment system 3 having the configuration of FIG. 2. The silica-containing water treatment system 5 illustrated in FIG. 3 includes a magnesium dissolving tank 30 in which a magnesium salt and an acid are mixed in silica-containing water and reacted at a pH of 7 or lower to prepare a mixed liquid in which magnesium-containing liquid and silica-containing water are mixed with each other, a magnesium reaction tank 32 for reacting the mixed liquid at a pH in the range of 10 to 12, and, as the removing unit, a flocculation tank 50, a floc formation tank 52, and settling tank 54.

[0058]

A silica-containing water pipe 38 is connected to a silica-containing water inlet of the magnesium dissolving tank 30. An outlet of the magnesium dissolving tank 30 and an inlet of the magnesium reaction tank 32 are connected by a magnesium-containing liquid pipe 40. An outlet of the magnesium reaction tank 32 and an inlet of the flocculation tank 50 are connected by a reaction liquid pipe 60. An outlet of the flocculation tank 50 and an inlet of the floc formation tank 52 are connected by a flocculated liquid pipe 62. An outlet of the floc formation tank 52 and an inlet of the settling tank 54 are connected by a floc formation liquid pipe 64. A treated water pipe 66 is connected to a treated water outlet of the settling tank 54. A sludge pipe 68 is connected to a sludge outlet of the settling tank 54. Stirring devices 34, 36, 56, and 58 that include a stirring blade are installed in the magnesium dissolving tank 30, the magnesium reaction tank 32, the

flocculation tank 50, and the floc formation tank 52, respectively, as stirring units. An acid addition pipe 44 and a magnesium salt addition pipe 46 are connected to the magnesium dissolving tank 30. A pH adjuster addition pipe 48 is connected to the magnesium reaction tank 32. An inorganic flocculating agent addition pipe 70 is connected to the flocculation tank 50. A polymer flocculating agent addition pipe 72 is connected to the floc formation tank 52.

[0059]

The silica-containing water that contains silica is supplied to the magnesium dissolving tank 30 through the silica-containing water pipe 38. In the magnesium dissolving tank 30, the acid is added to the silica-containing water through the acid addition pipe 44, and for example, water slurry of the magnesium salt is added thereto through the magnesium salt addition pipe 46. The magnesium salt, the acid, and the silica-containing water are mixed with each other by stirring of the stirring device 34, and reacted at a pH of 7 or lower to prepare a mixed liquid in which the magnesium-containing liquid and the silica-containing water are mixed with each other (a magnesium dissolving process). A solid magnesium salt may be added as it is to the magnesium dissolving tank 10 to be mixed with the acid.

[0060]

The mixed liquid which is obtained in the magnesium dissolving process, and in which the magnesium-containing liquid containing the magnesium salt and the acid and silica-containing water are mixed with each other, is supplied to magnesium reaction tank 32 through the magnesium-containing liquid pipe 40, and stirred by the stirring device 36. In addition, in the magnesium reaction tank 32, a pH adjuster is added to the mixed liquid through the pH adjuster addition pipe 48 and reacted at a pH in the range of 10 to 12, and the silica is insolubilized (a magnesium reaction process). The reaction liquid is supplied to the flocculation tank 50 through the reaction liquid pipe 60.

[0061]

In the flocculation tank 50, an inorganic flocculating agent is added to the reaction liquid through the inorganic flocculating agent addition pipe 70, and the insolubilized substances are flocculated (a flocculating process). The flocculated liquid is supplied to the floc formation tank 52 through the flocculated liquid pipe 62.

[0062]

In the floc formation tank 52, a polymer flocculating agent is added to the flocculated liquid through the polymer flocculating agent addition pipe 72, and the floc is formed (a floc formation process). The floc formation liquid is supplied to the settling tank 54 through the floc formation liquid pipe 64.

[0063]

In the settling tank 54, the floc-formed aggregate is solid-liquid separated (solid-liquid separating process). The treated water is discharged through the treated water pipe 66. On the other hand, sludge is discharged through the sludge pipe 68.

[0064]

At a stage subsequent to the silica-containing water treatment system 5, a reverse osmosis membrane (RO membrane) treatment, a decarbonation treatment, an ion exchange treatment, a distillation treatment, or the like may be further performed. The treated water obtained in the silica-containing water treatment system 5 has the silica removed at a high removal rate. Therefore, even when these treatments are performed at a later stage, the risk of scale formation will be low.

[0065]

Examples of the inorganic flocculating agent used in the flocculating process include an iron-based inorganic flocculating agent such as iron chloride and an aluminum-based inorganic flocculating agent such as polyaluminum chloride (PAC), and the iron-based inorganic flocculating agent is preferable from the viewpoints of chemical costs and a pH range for flocculation.

[0066]

The added amount of the inorganic flocculating agent is preferably in the range of 0.1 to 10 times, and more preferably in the range of 1 to 5 times, the amount of the added magnesium salt, in terms of a weight ratio. When the added amount of the inorganic flocculating agent is less than 0.1 times the amount of the added magnesium salt in terms of the weight ratio, the flocculation may be insufficient in some cases. When the added amount of the inorganic flocculating agent is more than 10 times the amount of the added magnesium salt in terms of the weight ratio, a sludge generation amount may become excessive in some cases.

[0067]

The pH in the flocculating process is, for example, in the range of 3 to 11. When the pH in the flocculating process is lower than 3 or higher than 11, poor flocculation may occur in some cases. Further, when the pH in the flocculating process is lower than 9, the silica can be dissolved from the floc. Therefore, it is desirable to perform the flocculating process at a pH in the range of 9 to 11.

[0068]

The temperature in the flocculating process is, for example, in the range of 1°C to 80°C. When the temperature in the flocculating process is lower than 1°C or higher than 80°C, poor flocculation may occur in some cases.

[0069]

Examples of the polymer flocculating agent used in the floc formation process include cationic polymer flocculating agents such as polyacrylamide-based or polyacrylic ester-based ones, anionic polymer flocculating agents, and nonionic polymer flocculating agents, and the cationic polymer flocculating agents are preferable from the viewpoint of flocculating property.

[0070]

Examples of a commercially available polymer flocculating agent include a cationic polymer flocculating agent such as ORFLOCK OX-304 (manufactured by Organo Corporation).

[0071]

The added amount of the polymer flocculating agent is preferably in the range of 0.1 to 10 mg/L and more preferably in the range of 1 to 5 mg/L, with respect to an amount of raw water. When the added amount of the polymer flocculating agent is less than 0.1 mg/L with respect to the amount of raw water, floc formation does not improve in some cases. When the added amount of the polymer flocculating agent is more than 10 mg/L, the polymer flocculating agent which is present by being dissolved in the treated water may remain in some cases.

[0072]

The pH in the floc formation process is, for example, in the range of 3 to 11. When the pH in the floc formation process is lower than 3 or higher than 11, poor flocculation may occur in some cases. Further, when the pH in the floc process is lower than 9, the silica can be dissolved from the floc. Therefore, it is desirable to perform the floc formation process at a pH within the range of 9 to 11.

[0073]

The temperature in the floc formation process is, for example, in the range of 1°C to 80°C. When the temperature in the floc formation process is lower than 1°C or higher than 80°C, poor flocculation may occur in some cases.

[0074]

In the flocculating treatment described above, an inorganic flocculating agent and a polymer flocculating agent are used for the flocculating process and the floc formation process. At least one of the inorganic flocculating agent, the polymer flocculating agent, and the like may be used, and at least one of an iron-based inorganic flocculating agent and a cationic polymer flocculating agent is preferably used. When the magnesium salt is

reacted to flocculate the insolubilized silica, using at least one of the iron-based inorganic flocculating agent and the cationic polymer flocculating agent can improve the flocculating property and the solid-liquid separation property.

[0075]

Examples of the solid-liquid separation include pressurized floatation treatment, membrane filtration treatment, and the like, in addition to settling separation, and the settling separation is preferable from the viewpoints of separability and the like.

Examples

[0076]

Hereinafter, the present invention will be more specifically described in detail with reference to an Example and Comparative Examples, but the present invention is not limited to the following Example.

[0077]

<Example 1 and Comparative Example 1>

A continuous water flow experiment was conducted for silica-containing water by using the treatment system 5 illustrated in FIG. 3 while changing the pH in the magnesium dissolving tank to 4, 5, 6, 7 (Example 1), 8, 9, 10 (Comparative Example 1), and the effect of removing silica was checked. Experimental Conditions are illustrated in Table 1.

[0078]

[Table 1]

Table 1: Experimental conditions

Flow rate of water		5 L/min
Silica-containing water	Silica concentration	50 mg/L
Magnesium dissolving tank	Mg salt	Water slurry (35 wt%) of magnesium hydroxide (Mg(OH) ₂)
	Injection amount	100 mg-Mg/L
	Acid	Hydrochloric acid
	pH	4 to 10
	Reaction temperature	25°C (room temperature)
Magnesium reaction tank	pH adjuster	Sodium hydroxide
	pH	11
	Reaction temperature	25°C (room temperature)
Flocculation tank	Inorganic flocculating agent	Ferric chloride FeCl ₃
	Injection amount	500 mg/L
	pH	11
	Reaction temperature	25°C (room temperature)
Floc formation tank	Polymer flocculating agent	Cationic ORFLOCK OX-304
	Injection amount	2 mg/L
	pH	11
	Reaction temperature	25°C (room temperature)

[0079]

Experimental results are illustrated in FIG. 4. The silica concentration was measured by molybdenum yellow absorption spectrophotometry using a spectrophotometer (U-3900, manufactured by Hitachi High-Tech Science Corporation.).

[0080]

As illustrated in FIG. 4, it was found that when the pH in the magnesium dissolving tank was 7 or lower, the silica concentration of the flocculation and settlement-treated water was successfully reduced.

[0081]

<Comparative Example 2>

Experimental results in a case where the present method is adopted while changing the added amount of the magnesium salt (250 mg/L, 500 mg/L, 750 mg/L, 1000 mg/L, and 1500 mg/L), under conditions (magnesium salt: $\text{Mg}(\text{OH})_2$ + sulfuric acid, dissolving pH: 9.5, and reaction pH: 11) described in Non Patent Literature 1 are illustrated in FIG. 5. The results of Example 1 in which the pH in the magnesium dissolving tank was set to 7 (added amount of magnesium salt: 230 mg/L, 460 mg/L, and 920 mg/L) are also illustrated in FIG. 5.

[0082]

As illustrated in FIG. 5, when performing comparison with the same added amount of the magnesium salt, the result was that a silica removal rate of a method of Example 1 was higher than that of the method of Comparative Example 2 described in Non Patent Literature 1.

[0083]

The above results indicate that treated water can be obtained with a high degree of removal of silica. Therefore, even when a reverse osmosis membrane treatment is performed in a subsequent stage and the treated water is recovered and reused, the risk of silica scale or the like can be reduced.

[0084]

As shown above, the silica-containing water was efficiently treated by the method of Example 1.

REFERENCE SIGNS LIST

[0085]

1, 3, 5: silica-containing water treatment system

10, 30: magnesium dissolving tank

12, 32: magnesium reaction tank

14, 16, 34, 36, 56, 58: stirring device

18, 38: silica-containing water pipe

20, 42, 66: treated water pipe

22, 44: acid addition pipe

24, 46: magnesium salt addition pipe

26, 40: magnesium-containing liquid pipe

28, 48: pH adjuster addition pipe

50: flocculation tank

52: floc formation tank

54: settling tank

60: reaction liquid pipe

62: flocculated liquid pipe

64: floc formation liquid pipe

68: sludge pipe

70: inorganic flocculating agent addition pipe

72: polymer flocculating agent addition pipe

CLAIMS

[Claim 1]

A silica-containing water treatment system, comprising:

a magnesium dissolving unit in which a magnesium salt and an acid are mixed with each other and reacted at a pH of 4 to 7 to prepare a magnesium-containing liquid; and

a magnesium reaction unit in which a mixed liquid obtained by mixing silica-containing water and the magnesium-containing liquid is reacted at a pH in a range of 10 to 12.

[Claim 2]

The silica-containing water treatment system according to claim 1, comprising:

a magnesium dissolving tank as the magnesium dissolving unit in which the magnesium salt and the acid are mixed with each other and reacted at a pH of 4 to 7 to prepare the magnesium-containing liquid; and

a magnesium reaction tank as the magnesium reaction unit in which the mixed liquid obtained by mixing the silica-containing water and the magnesium-containing liquid is reacted at a pH in a range of 10 to 12.

[Claim 3]

The silica-containing water treatment system according to claim 1, comprising:

a magnesium dissolving tank as the magnesium dissolving unit in which the magnesium salt and the acid are mixed in silica-containing water and reacted at a pH of 4 to 7 to prepare the mixed liquid including a mixture of the magnesium-containing liquid and the silica-containing water; and

a magnesium reaction tank as the magnesium reaction unit in which the mixed liquid is reacted at a pH in a range of 10 to 12.

[Claim 4]

The silica-containing water treatment system according to any one of claims 1 to 3, further comprising:

a removing unit for separating and removing an insolubilized substance obtained by a reaction performed by the magnesium reaction unit, at a stage subsequent to the magnesium reaction unit.

[Claim 5]

The silica-containing water treatment system according to claim 4, wherein the removing unit includes:

a flocculation unit for flocculating the insolubilized substance using a flocculating agent; and

a solid-liquid separating unit for solid-liquid separating the flocculated substance, at a stage subsequent to the flocculation unit.

[Claim 6]

The silica-containing water treatment system according to claim 5, wherein

the flocculating agent is at least one of an iron-based inorganic flocculating agent and a cationic polymer flocculating agent.

[Claim 7]

A silica-containing water treatment method comprising:

a magnesium dissolving process in which a magnesium salt and an acid are mixed with each other and reacted at a pH of 4 to 7 to prepare a magnesium-containing liquid; and

a magnesium reaction process in which a mixed liquid obtained by mixing silica-containing water and the magnesium-containing liquid is reacted at a pH in a range of 10 to 12.

[Claim 8]

The silica-containing water treatment method according to claim 7, wherein

in the magnesium dissolving process, the magnesium salt and the acid are mixed with each other and reacted at a pH of 4 to 7 to prepare the magnesium-containing liquid; and

in the magnesium reaction process, the mixed liquid obtained by mixing the silica-containing water and the magnesium-containing liquid is reacted at a pH in a range of 10 to 12.

[Claim 9]

The silica-containing water treatment method according to claim 7, wherein

in the magnesium dissolving process, the magnesium salt and the acid are mixed in silica-containing water and reacted at a pH of 4 to 7 to prepare the mixed liquid including a mixture of the magnesium-containing liquid and the silica-containing water, and

in the magnesium reaction process, the mixed liquid is reacted at a pH in a range of 10 to 12.

[Claim 10]

The silica-containing water treatment method according to any one of claims 7 to 9, further comprising:

a removing process of separating and removing an insolubilized substance obtained by a reaction performed in the magnesium reaction process, at a stage subsequent to the magnesium reaction process.

[Claim 11]

The silica-containing water treatment method according to claim 10, wherein the removing process includes:

a flocculation process of flocculating the insolubilized substance using a flocculating agent; and

a solid-liquid separating process of solid-liquid separating the flocculated substance, at a stage subsequent to the flocculation process.

[Claim 12]

The silica-containing water treatment method according to claim 11, wherein
the flocculating agent is at least one of an iron-based inorganic flocculating agent
and a cationic polymer flocculating agent.