

Description

WATER TREATMENT METHOD AND APPARATUS AND METHOD FOR REGENERATING ION EXCHANGE RESIN

Technical Field

[0001]

The present invention relates to a water treatment method and apparatus, suitable for, for example, treating wastewater in the electronic industry. The present invention also relates to a method for regenerating an ion exchange resin.

Background Art

[0002]

A water treatment method using an ion exchange resin and a reverse osmosis membrane is known. Patent Literature 1 discloses passing wastewater containing free acids, in the copper alloy industry, the plating industry, the iron and steel industry, the food industry, or the like, through an ion exchange resin and then separating the wastewater into a concentrated liquid and a membrane permeate liquid by a reverse osmosis method.

[0003]

Patent Literature 2 discloses a steam plant that can reduce the water consumption and a method for operating the same. This literature describes passing water softened in a softener vessel including a resin through a reverse osmosis unit including a semipermeable membrane, supplying the permeate water from the reverse osmosis unit to a boiler, and using the concentrated liquid in the reverse osmosis unit for the regeneration of the softener vessel.

Prior Art Literatures

Patent Literature

[0004]

Patent Literature 1: JP S50-105546A

Patent Literature 2: JP 2013-212504A

Summary of Invention

Problems to be solved by the Invention

[0005]

According to the technique described in Patent Literature 2, by using the concentrated liquid from the reverse osmosis unit for the regeneration of the softener vessel (resin), the amount of raw water that is usually used for washing a softener vessel can be decreased.

[0006]

However, in a water treatment method using an ion exchange resin and a reverse osmosis membrane, when sulfate ions SO_4^{2-} and carbonate ions CO_3^{2-} are contained in water to be treated, these divalent anions pass through the ion exchange resin and are concentrated in concentrated water from the reverse osmosis membrane. When this concentrated water is used for the regeneration of the ion exchange resin, CaSO_4 and CaCO_3 may precipitate, and therefore in such a case, using the concentrated water from the reverse osmosis membrane for the regeneration of the ion exchange resin should be avoided.

[0007]

On the other hand, as a regenerant for regenerating an ion exchange resin that is used for softening treatment, generally, a high concentration NaCl aqueous solution is often used. In this case, however, the costs for the regenerant are high, and a step of dissolving solid NaCl is needed, and therefore the operation is complicated.

[0008]

It is an object of the present invention to provide a water treatment method using an ion exchange resin and a reverse osmosis membrane in which, even when sulfate ions SO_4^{2-} and carbonate ions CO_3^{2-} are contained in water to be treated, the regeneration of the ion exchange resin can be performed in a simpler manner and at lower costs.

[0009]

It is another object of the present invention to provide a water treatment apparatus suitable for carrying out the above method.

[0010]

It is still another object of the present invention to provide a method for regenerating an ion exchange resin, in which the regeneration of the ion exchange resin can be performed in a simpler manner and at lower costs, and particularly, in which reverse osmosis membrane concentrated water obtained from a water treatment method using an ion exchange resin and a reverse osmosis membrane can be used for the regeneration of the ion exchange resin, even when sulfate ions SO_4^{2-} and carbonate ions CO_3^{2-} are contained in water to be treated by the water treatment.

Means for solving the Problems

[0011]

An aspect of the present invention provides

a water treatment method comprising:

a softening step of softening, by using an ion exchange resin, water to be treated containing one or two types of divalent anions selected from the group consisting of SO_4^{2-} and CO_3^{2-} , a hardness component, Na^+ and Cl^- ;

a nanofiltration step of separating, by using a nanofiltration membrane, the water softened in the softening step into permeate water and a concentrated liquid from the nanofiltration membrane;

a reverse osmosis step of separating, by using a reverse osmosis membrane, the permeate water from the nanofiltration membrane into permeate water and concentrated water from the reverse osmosis membrane; and

an ion exchange resin regeneration step of regenerating the ion exchange resin by using the concentrated water from the reverse osmosis membrane.

[0012]

Another aspect of the present invention provides

a water treatment apparatus comprising:

a softening unit comprising an ion exchange resin;

a nanofiltration unit comprising a nanofiltration membrane;

a reverse osmosis unit comprising a reverse osmosis membrane,

a line connecting a softened water outlet of the softening unit to an inlet of the nanofiltration unit;

a line connecting a permeate water outlet of the nanofiltration unit to an inlet of the reverse osmosis unit; and

a line connecting a concentrated liquid outlet of the reverse osmosis unit to a regenerant inlet of the softening unit.

[0013]

A further aspect of the present invention provides

a method for regenerating an ion exchange resin, comprising:

a softening step of softening, by using an ion exchange resin, water to be treated containing one or two types of divalent anions selected from the group consisting of SO_4^{2-} and CO_3^{2-} , a hardness component, Na^+ and Cl^- ;

a nanofiltration step of separating, by using a nanofiltration membrane, the water softened in the softening step into permeate water and a concentrated liquid from the

nanofiltration membrane;

a reverse osmosis step of separating, by using a reverse osmosis membrane, the permeate water from the nanofiltration membrane into permeate water and concentrated water from the reverse osmosis membrane; and

an ion exchange resin regeneration step of regenerating an ion exchange resin (which may be the ion exchange resin used in the softening step, or may be another ion exchange resin different from the ion exchange resin used in the softening step) by using the concentrated water from the reverse osmosis membrane.

Effects of the Invention

[0014]

According to the present invention, there is provided a water treatment method using an ion exchange resin and a reverse osmosis membrane in which, even when sulfate ions SO_4^{2-} and carbonate ions CO_3^{2-} are contained in water to be treated, the regeneration of the ion exchange resin can be performed in a simpler manner and at lower costs.

[0015]

In addition, according to the present invention, there is provided a water treatment apparatus suitable for carrying out the above method.

[0016]

Further, according to the present invention, there is provided a method for regenerating an ion exchange resin, in which the regeneration of the ion exchange resin can be performed in a simpler manner and at lower costs, and particularly, in which reverse osmosis membrane concentrated water obtained from a water treatment method using an ion exchange resin and a reverse osmosis membrane can be used for the regeneration of the ion exchange resin, even when sulfate ions SO_4^{2-} and carbonate ions CO_3^{2-} are contained in water to be treated by the water treatment.

Brief Description of the Drawings

[0017]

Figure 1 is a process flow diagram illustrating an example of the water treatment apparatus of the present invention.

Description of Embodiments

[0018]

A water treatment method or a method for regenerating an ion exchange resin according to the present invention includes a softening step, a nanofiltration step, a reverse osmosis step, and an ion exchange resin regeneration step.

[0019]

[Nanofiltration Membrane and Reverse Osmosis Membrane]

In relation to the present invention, a membrane having a NaCl rejection rate of 5% or more and less than 93% under the conditions of a NaCl concentration of 500 mg/L, a pH of 6.5, a temperature of 25°C, and an operating pressure of 1.5 MPa is referred to as a nanofiltration (NF) membrane, and a membrane having a NaCl rejection rate of 93% or more under the same conditions is referred to as a reverse osmosis (RO) membrane.

[0020]

The rejection rate is obtained by the following formula:

[0021]

[Formula 1]

rejection rate (%)

$$= \frac{\left[\frac{(\text{conc. in raw water} + \text{conc. in concentrated water})}{2} - \text{conc. in permeate water} \right]}{\frac{(\text{conc. in raw water} + \text{conc. in concentrated water})}{2}}$$

conc.: concentration

[0022]

[Softening Step]

In the softening step, water to be treated is softened by using an ion exchange resin. The water to be treated contains a type of divalent anions, a hardness component, sodium ions Na^+ , and chlorine ions Cl^- . The type of the divalent anions is one or two types of anions selected from the group consisting of sulfate ions SO_4^{2-} and carbonate ions CO_3^{2-} . The type of the divalent anions is particularly SO_4^{2-} .

[0023]

The hardness component is known in the field of water treatment and is typically a divalent cation. Ca^{2+} and Mg^{2+} are typical hardness components. In the softening step, the concentration of the hardness component is reduced.

[0024]

As the ion exchange resin, a known ion exchange resin used for softening treatment,

particularly a Na-form strongly acidic cation exchange resin, can be appropriately used. There are a gel type, a porous type and an MR type, and any of these may be used. As the ion exchange resin, for example, Amberjet 1020 (trade name, the same applies below), Amberjet 1024, Amberlite IR124, and Amberlite IR120B manufactured by ORGANO CORPORATION can be used.

[0025]

[Nanofiltration Step]

In this step, the water softened in the softening step (softened water) is passed through an NF membrane to obtain permeate water and concentrated water from the NF membrane. In other words, the softened water is separated into permeate water from the NF membrane (the liquid having permeated the NF membrane) and concentrated water from the NF membrane (the liquid not having permeated the NF membrane) by using the NF membrane.

[0026]

The permeate water from the NF membrane is supplied to the reverse osmosis step. The concentrated water from the NF membrane is appropriately released to the outside or treated as industrial waste depending on the concentrations of the divalent anions or the like.

[0027]

The NF membrane is used for reducing the divalent anion (SO_4^{2-} and/or CO_3^{2-}) concentrations of the liquid which is then supplied to an RO membrane. Thus, CaSO_4 and CaCO_3 are prevented from precipitating when concentrated water from the RO membrane is used for the regeneration of the ion exchange resin. Therefore, the divalent anions are preferably concentrated in the concentrated water from the NF membrane as much as possible. On the other hand, monovalent ions (Na^+ and Cl^-) are preferably allowed to permeate the NF membrane as much as possible, allowed to be present in the concentrated water from the RO membrane as much as possible, and are used as regenerants for the ion exchange resin.

[0028]

From this viewpoint, the NaCl rejection rate of the NF membrane is preferably 70% or less, more preferably 50% or less. The divalent anion (SO_4^{2-} and/or CO_3^{2-}) rejection rate of the NF membrane is preferably 90% or more, more preferably 98% or more.

[0029]

As the NF membrane, for example, NF-245 (trade name) manufactured by The Dow Chemical Company can be used.

[0030]

[Reverse Osmosis Step]

In this step, the permeate water from the NF membrane is passed through the RO membrane to obtain permeate water and concentrated water from the RO membrane. In other words, the permeate water from the NF membrane is separated into permeate water from the RO membrane (the liquid having permeated the RO membrane) and concentrated water from the RO membrane (the liquid not having permeated the RO membrane) by using the RO membrane.

[0031]

The permeate water from the RO membrane is water having high purity. Therefore, it can be released to the outside but is preferably reused as recovered water.

[0032]

Na^+ and Cl^- are concentrated in the concentrated water from the RO membrane. On the other hand, SO_4^{2-} and CO_3^{2-} are separated by the NF membrane, and the concentrations of SO_4^{2-} and CO_3^{2-} in the concentrated water from the RO membrane can be very low. Therefore, this concentrated water is suitable as a regenerant for the ion exchange resin, and thus supplied to the ion exchange resin regeneration step.

[0033]

An RO membrane that can be used at higher pressure is preferred from the viewpoint that more Na^+ and Cl^- can be contained in the RO membrane concentrated water.

[0034]

As the RO membrane, for example, SW-30HR (trade name) manufactured by The Dow Chemical Company can be used.

[0035]

[Ion Exchange Resin Regeneration Step]

In this step, the ion exchange resin is regenerated by using the concentrated water from the RO membrane. The concentrated water from the RO membrane can be used as a regenerant for the ion exchange resin used for the softening treatment. In other words, when water to be treated is treated in the softening step, the nanofiltration step, and then the reverse osmosis step, the concentrated water from the RO membrane obtained from the reverse osmosis step may be used for the regeneration of the ion exchange resin used in the softening step. In the water treatment method or the water treatment apparatus, this embodiment will be often adopted.

[0036]

However, this is not limiting, and the concentrated water from the RO membrane may be used for the regeneration of an ion exchange resin different from the ion exchange resin used in the softening step according to another embodiment. In the method for regenerating an ion exchange resin, the former embodiment (the ion exchange resin used for the softening treatment

is regenerated) may be adopted, or the latter may be adopted.

[0037]

Before the regeneration of the ion exchange resin, NaCl may be added to the concentrated water from the RO membrane as needed, to increase the NaCl concentration. The concentrated water from the RO membrane may be used as a regenerant after being further concentrated by another method such as an evaporation method.

[0038]

Before the regeneration of the ion exchange resin, the concentrated water from the RO membrane may be subjected to another treatment as needed. For example, in order to remove SO_4^{2-} and CO_3^{2-} , or in order to remove fluorine ions (F^-), the concentrated water from the RO membrane may be treated by a method using an ion exchange resin or a fluorine adsorbent. Alternatively, the concentrated water from the RO membrane can be treated by a decarbonation method or the like.

[0039]

[Water Treatment Apparatus]

The present invention will be described below with reference to the drawing, but the present invention is not limited by this. A method of the present invention can be carried out by a water treatment apparatus having the process flow shown in Figure 1.

[0040]

This water treatment apparatus includes a softening unit 3 including an ion exchange resin, a nanofiltration unit (NF unit) 4 including a nanofiltration membrane, and a reverse osmosis unit (RO unit) 5 including a reverse osmosis membrane. For the structures of the individual units of the softening unit, the nanofiltration unit, and the reverse osmosis unit, known structures can be appropriately adopted.

[0041]

The softened water outlet of the softening unit 3 and the inlet of the NF unit 4 are connected by a line L2 and can communicate with each other. The permeate water outlet of the NF unit 4 and the inlet of the RO unit 5 are connected by a line L3 and can communicate with each other. The concentrated liquid outlet of the RO unit 5 and the regenerant inlet of the softening unit 3 are connected by lines L6 and L7 (an RO membrane concentrated water tank 6 is provided between these lines) and can communicate with each other.

[0042]

This water treatment apparatus has a tank 1 for water to be treated, and a pump 2 is provided in a line (L1) connecting the tank 1 for water to be treated and the softening unit 3.

The tank 1 for water to be treated, the pump 2, and the RO membrane concentrated water tank 6 are not necessarily needed and are appropriately provided. When the RO membrane concentrated water tank 6 is not provided, the concentrated liquid outlet of the RO unit and the regenerant inlet of the softening unit are connected by a line. In this case, for example, by providing a plurality of softening units in parallel, it is possible to, while performing water treatment in one softening unit, regenerate ion exchange resins in other softening units.

[0043]

Each line can be formed by appropriately using piping. A valve and an instrumentation and control device can be appropriately provided in each line according to a purpose such as switching between water treatment operation and ion exchange resin regeneration operation.

[0044]

When water treatment is performed, water to be treated is supplied from the tank 1 for water to be treated to the softening unit 3 through the line L1. At this time, the pressure of the water to be treated is increased by the pump 2. The softened water is supplied from the softening unit 3 to the NF unit 4 through the line L2. The permeate liquid from the NF membrane is supplied to the RO unit through the line L3. The concentrated water from the NF membrane is discharged from the water treatment apparatus through the line L4 and appropriately released to the outside or treated as industrial waste. The permeate liquid from the RO membrane is discharged out of the apparatus through the line L5 and appropriately used as recovered water or released to the outside. The concentrated liquid from the RO membrane is supplied to the RO membrane concentrated water tank 6 through the line L6.

[0045]

When the ion exchange resin provided in the softening unit 3 is regenerated, the RO membrane concentrated water is supplied from the RO membrane concentrated water tank 6 to the softening unit through the line L7, and the ion exchange resin is regenerated by the RO membrane concentrated water. A regeneration waste liquid is discharged out of the water treatment apparatus from a line L8 and appropriately released to the outside or treated as industrial waste.

[0046]

[Process Conditions]

Typical examples of process conditions for the softening step feed liquid (water to be treated), the NF step feed liquid (softened water), and the RO step feed liquid (NF membrane permeate water) are shown in Tables 1 and 2.

[0047]

The NaCl concentration in the concentrated water obtained from the RO step is preferably 2% by mass or more, more preferably 4% by mass or more, from the viewpoint of efficiently regenerating the ion exchange resin. The NaCl concentration is preferably 10% by mass or less from the viewpoint of proper osmotic pressure. When the typical process conditions shown in Tables 1 and 2 are adopted, it is easy to set the NaCl concentration in the RO membrane concentrated water in the above preferred range as a result.

[0048]

The NaCl concentration in the RO membrane permeate water is preferably 150 mg/L or less from the viewpoint of recovery and reuse.

[0049]

[Table 1]

Table 1 Typical Process Conditions (1)

	Na ⁺ concentration	Cl ⁻ concentration	Ca ²⁺ concentration	Mg ²⁺ concentration
Softening step feed liquid	No special conditions		Each is 300 mg/L or less, preferably 200 mg/L or less. From the viewpoint of the moderateness of the amount of the ion exchange resin.	
NF step feed liquid	Each is 250 mg/L or more and 40000 mg/L or less, preferably 500 mg/L or more and 20000 mg/L or less. The lower limit is set from the viewpoint of the suitability of the RO membrane concentrated water as a regenerant. The upper limit is set from the viewpoint of moderate osmotic pressure.		A concentration at which neither Ca salts nor Mg salts precipitate. Particularly a concentration at which the concentrations of CaSO ₄ , CaCO ₃ , MgSO ₄ , and MgCO ₃ do not exceed the solubilities.	
RO step feed liquid	Each is 500 mg/L or more and 80000 mg/L or less, preferably 1000 mg/L or more and 40000 mg/L or less. The lower limit is set from the viewpoint of the suitability of the RO membrane concentrated water as a regenerant. The upper limit is set from the viewpoint of moderate osmotic pressure.			

[0050]

[Table 2]

Table 2 Typical Process Conditions (2)

	SO_4^{2-} concentration	CO_3^{2-} concentration	Temperature	Pressure
Softening step feed liquid	No special conditions	No special conditions	Normal temperature	Normal pressure
NF step feed liquid	10 mg/L or more and 10000 mg/L or less, preferably 100 mg/L or more and 5000 mg/L or less. The lower limit is set from the viewpoint of the effectiveness of the NF step. The upper limit is set from the viewpoint of suppressing salt precipitation in the RO step.	About 10 mg- CaCO_3 /L or less. A concentration at which no Ca salts precipitate.	Normal temperature. The upper limit of working temperatures of a common NF membrane and RO membrane are each 40°C.	About 0.3 MPa or more and 1.5 MPa or less. The upper limit of working pressure of a common NF membrane/RO membrane is about 4.1 MPa.
RO step feed liquid	Less than 10 mg/L, preferably 5 mg/L or less. From the viewpoint of the preferability of the RO membrane concentrated water as a regenerant.			About 0.50 MPa or more and 8.0 MPa or less. The upper limit for a common RO membrane for seawater desalination is about 8.3 MPa.

[0051]

According to the present invention, even when SO_4^{2-} and CO_3^{2-} are contained in water to be treated, the RO membrane concentrated liquid can be used for regeneration of an ion exchange resin. Therefore, the costs for the regenerant for the ion exchange resin can be reduced, and the step of dissolving solid NaCl can be omitted, and therefore operation management is easy.

[0052]

In addition, according to the present invention, the softened water is treated by the NF membrane before being treated by the RO membrane. According to the present invention, compared with a case where the softened water is directly treated by the RO membrane, the salt concentrations in the liquid that should be subjected to RO membrane treatment can be decreased, that is, the osmotic pressure can be decreased. Therefore, it is easy to increase the concentration rate in the RO membrane to increase the NaCl concentration in the RO membrane concentrated liquid, or it is possible to lower the operating pressure of the RO membrane.

[0053]

Aluminum ions may promote the formation of silica scale when they coexist with ionic silica. However, according to the present invention, even when aluminum ions coexist in water to be treated, by removing the aluminum ions by the ion exchange resin, the aluminum ions can

be prevented from flowing into the NF membrane and the RO membrane in the subsequent stages.

Examples

[0054]

The present invention will be described in more detail below based on an Example, but the present invention is not limited by this.

[0055]

[Example 1]

• Softening Step

As the liquid to be treated, released water from a semiconductor factory, whose properties are shown in Table 3, was used. This released water was subjected to softening treatment using a softening unit including an ion exchange resin, to remove Ca ions. The properties of the water after the softening treatment are also shown in Table 3.

[0056]

The softening unit (ion exchange apparatus) and the operating conditions used are as follows:

Ion exchange resin: Amberjet 1020 (trade name) manufactured by ORGANO CORPORATION,

Amount of resin: 1 L,

Column used: Φ (diameter) 45 mm $\times$ H (height) 600 mm,

Amount of water treated: 40 L,

SV (space velocity): 20 (1/h),

Operating temperature and pressure: normal temperature, normal pressure (25°C, 0.10 MPa).

[0057]

[Table 3]

Table 3 Released Water Properties

	Unit	Released water	Softened water
pH	-	8.0	8.0
Na	mg/L	2200	2400
Cl	mg/L	2100	2100
Ca	mg/L	200	<1
SO ₄	mg/L	2400	2400

[0058]

• NF Step

The softened water shown in Table 3 was concentrated by using a flat NF membrane, to obtain concentrated water and permeate water shown in Table 4. The water after the softening (40 L) was concentrated 2-fold, and 20 L of the concentrated water and 20 L of the permeate water were obtained.

[0059]

The NF membrane and the operating conditions used are as follows:

NF membrane: NF-245 (trade name) Φ 75 mm flat membrane manufactured by The Dow Chemical Company,

Operating pressure: 0.75 MPa,

Water temperature: 25°C.

[0060]

- RO Step

Next, the permeate water from the NF membrane was further concentrated using a flat RO membrane, to obtain concentrated water and permeate water shown in Table 4. The NF membrane permeate water (20 L) was concentrated about 12-fold, and 1.7 L of the concentrated water and 18.3 L of the permeate water were obtained.

[0061]

The RO membrane and the operating conditions used are as follows:

RO membrane: SW30-HR (trade name) Φ 75 mm flat membrane manufactured by The Dow Chemical Company,

Operating pressure: 4.5 MPa,

Water temperature: 25°C.

[0062]

[Table 4]

Table 4 Example 1 Test Results

	Unit	Permeate water after NF membrane concentration	Concentrated water after NF membrane concentration	NF membrane rejection rate (%)	Permeate water after RO membrane concentration	Concentrated water after RO membrane concentration	RO membrane rejection rate (%)
pH	-	6.6	8.3	-	6.9	8.2	
Na	mg/L	1800	3000	33.3	60	21000	99.5
Cl	mg/L	1700	2500	26.1	60	20000	99.4
Ca	mg/L	<1	<1	-	<1	<1	-
SO ₄	mg/L	3	4800	99.9	<1	3	-

[0063]

This RO membrane concentrated water has high Na^+ and Cl^- concentrations and can be used as a regenerant for the ion exchange resin as it is. The NF membrane concentrated water and the RO membrane permeate water were discarded.

[0064]

[Comparative Example 1]

The softened water shown in Table 3 (40 L) was directly concentrated by using a flat RO membrane, without performing treatment by an NF membrane. The RO membrane and the operating pressure and the water temperature in the RO step were the same as those of Example 1. The softened water was concentrated about 8-fold, and concentrated water shown in Table 5 (5 L) and permeate water (35 L) were obtained.

[0065]

[Table 5]

Table 5 Comparative Example 1 Test Results

	Unit	Concentrated water
pH	-	8.0
Na	mg/L	19000
Cl	mg/L	17000
Ca	mg/L	<1
SO ₄	mg/L	19000

[0066]

At the same operating pressure as Example 1 (4.5 MPa), the softened water was concentrated only up to about 8-fold due to the influence of the osmotic pressure. Compared with the RO membrane concentrated water in Example 1, the RO membrane concentrated water in Comparative Example 1 has slightly lower Na^+ and Cl^- concentrations. This RO membrane concentrated water contains SO_4^{2-} at a high concentration and is therefore unsuitable as a regenerant for an ion exchange resin (the possibility of CaSO_4 precipitation is high during the ion exchange resin regeneration).

Industrial Applicability

[0067]

The present invention is useful for treating wastewater from a factory such as a semiconductor factory or a sugar refining factory, and for recovering water having high purity.

Reference Signs List

[0068]

- 1 tank for water to be treated
- 2 pump
- 3 softening unit
- 4 nanofiltration unit (NF unit)
- 5 reverse osmosis unit (RO unit)
- 6 RO membrane concentrated water tank

Claims

1. A water treatment method comprising:
 - a softening step of softening, by using an ion exchange resin, water to be treated containing one or two types of divalent anions selected from the group consisting of SO_4^{2-} and CO_3^{2-} , a hardness component, Na^+ and Cl^- ;
 - a nanofiltration step of separating, by using a nanofiltration membrane, the water softened in the softening step into permeate water and a concentrated liquid from the nanofiltration membrane;
 - a reverse osmosis step of separating, by using a reverse osmosis membrane, the permeate water from the nanofiltration membrane into permeate water and concentrated water from the reverse osmosis membrane; and
 - an ion exchange resin regeneration step of regenerating the ion exchange resin by using the concentrated water from the reverse osmosis membrane.
2. The method according to claim 1, wherein the water softened in the softening step has a SO_4^{2-} concentration of 10 mg/L or more and 10000 mg/L or less and a CO_3^{2-} content of 10 mg/L or less in terms of CaCO_3 .
3. The method according to claim 1 or 2, wherein in the permeate water from the nanofiltration membrane has a SO_4^{2-} concentration of less than 10 mg/L.
4. The method according to any one of claims 1 to 3, wherein the type of the divalent anions is SO_4^{2-} .
5. A water treatment apparatus comprising:
 - a softening unit comprising an ion exchange resin;
 - a nanofiltration unit comprising a nanofiltration membrane;
 - a reverse osmosis unit comprising a reverse osmosis membrane,
 - a line connecting a softened water outlet of the softening unit to an inlet of the nanofiltration unit;
 - a line connecting a permeate water outlet of the nanofiltration unit to an inlet of the reverse osmosis unit; and
 - a line connecting a concentrated liquid outlet of the reverse osmosis unit to a regenerant

inlet of the softening unit.

6. A method for regenerating an ion exchange resin, comprising:

a softening step of softening, by using an ion exchange resin, water to be treated containing one or two types of divalent anions selected from the group consisting of SO_4^{2-} and CO_3^{2-} , a hardness component, Na^+ and Cl^- ;

a nanofiltration step of separating, by using a nanofiltration membrane, the water softened in the softening step into permeate water and a concentrated liquid from the nanofiltration membrane;

a reverse osmosis step of separating, by using a reverse osmosis membrane, the permeate water from the nanofiltration membrane into permeate water and concentrated water from the reverse osmosis membrane; and

an ion exchange resin regeneration step of regenerating an ion exchange resin by using the concentrated water from the reverse osmosis membrane.