

DESCRIPTION

Title of Invention

MAGNESIUM RECOVERY METHOD AND MAGNESIUM RECOVERY
5 APPARATUS

Technical Field

[0001]

The present invention relates to a method and apparatus for recovering
10 magnesium from seawater by electrolysis of seawater.

Priority is claimed on Japanese Patent Application No. 2010-203353, filed
September 10, 2010, the content of which is incorporated herein by reference.

Background Art

15 [0002]

In recent years, high specific strength magnesium has garnered attention as a
next-generation structural material, and its demand is expected to increase hereafter.
However, magnesium, which is primarily refined from the mineral, is unevenly
distributed in limited geographical areas, and it would be desirable to establish
20 procurement methods apart from importation of magnesium in order to secure stable
supply in the future.

[0003]

As is well known, magnesium exists as a mineral, and is also contained in
seawater. Accordingly, if magnesium could be recovered from seawater, it would
25 greatly contribute to stable supply of magnesium. On the other hand, when recovering

large quantities of magnesium from seawater, there is the possibility of impacting the environment, such as by changing seawater composition. Accordingly, magnesium recovery from seawater must be conducted without impact on the environment.

[0004]

5 Patent Document 1 shows an electrolysis tank for obtaining fresh water, chlorine gas, and magnesium hydroxide from seawater, and Patent Document 2 shows a method in which pH of deep seawater is electrolyzed, or pH is raised by addition of alkali, and hydroxides such as Mg and Ca are precipitated, and recovered as precipitate.

10 Citation List

Patent Document

[0005]

Patent Document 1: Japanese Unexamined Patent Application, First Publication
No. S51-77586

15 Patent Document 2: Japanese Unexamined Patent Application, First Publication
No. 2007-167786

Summary of Invention

Technical Problem

20 [0006]

In light of the pertinent circumstances, the present invention offers a magnesium recovery method and magnesium recovery apparatus which are capable of recovering magnesium from seawater without imposing burdens on the environment.

25 Solution to Problem

[0007]

The present invention pertains to a magnesium recovery method including: electrolyzing seawater; separating anodic electrolyzed water and cathodic electrolyzed water produced by electrolysis of the seawater; inputting alkaline material into the anodic
5 electrolyzed water to adjust pH; precipitating magnesium as magnesium hydroxide in the cathodic electrolyzed water, and recovering the magnesium hydroxide; and intermixing the anodic electrolyzed water after pH adjustment and the cathodic electrolyzed water after recovery of the magnesium hydroxide and discharging the intermixed water in a state where a pH of the intermixed water is identical to a pH of the seawater.

10 [0008]

In this case, the alkaline material may be waste concrete. Iron, which is a soluble metal, may be used in the anode-side electrode to cause dissolution of ferric ions in the anodic electrolyzed water in the seawater electrolysis process.

[0009]

15 In addition, the present invention pertains to a magnesium recovery apparatus, including: an electrolysis tank having an anode and a cathode; a barrier film which partitions an interior of the electrolysis tank into an anode-side region containing the anode, and a cathode-side region containing the cathode; a first treatment tank which stores anodic electrolyzed water produced in the anode-side region; a second treatment
20 tank which stores cathodic electrolyzed water produced in the cathode-side region; a power-supply unit which supplies power to the anode and the cathode; an alkaline material input device which inputs alkaline material to the first treatment tank; and a recovery unit which recovers magnesium hydroxide precipitated in the second treatment tank, in which wastewater from the first treatment tank and wastewater from the second
25 treatment tank are intermixed, and discharged in a state where a pH of the intermixed

water is identical to a pH of seawater.

[0010]

In this case, the power-supply unit may have at least one photovoltaic cell, fuel cell, wind power generator, wave power generator, ocean thermal power generator, or
5 solar thermal power generator. The power-supply unit may contain a fuel cell which uses hydrogen gas generated on the cathode-side region, and oxygen gas generated on the anode-side region. The alkaline material inputted from the alkaline material input device may be waste concrete. Furthermore, the anode may contain iron as a consumable electrode, and the consumable electrode may dissolve ferric ions.

10

Advantageous Effects of Invention

[0011]

According to the magnesium recovery method of the present invention, seawater is electrolyzed, anodic electrolyzed water and cathodic electrolyzed water produced by
15 the electrolysis of seawater are separated, alkaline material is inputted into the anodic electrolyzed water to adjust pH, magnesium is precipitated as magnesium hydroxide in the cathodic electrolyzed water, and recovered, and the anodic electrolyzed water after pH adjustment and the cathodic electrolyzed water after magnesium hydroxide recovery are intermixed, and discharged with a pH identical to that of seawater. Consequently,
20 according to the present invention, magnesium can be recovered from seawater without impact on the environment.

[0012]

In the magnesium recovery method of the present invention, it is possible to concomitantly perform treatment of industrial waste products when using waste concrete
25 as the alkaline material.

[0013]

In the magnesium recovery method of the present invention, when using iron, which is a soluble metal, in the anode-side electrode, ferric ions are dissolved in the anodic electrolyzed water in the seawater electrolysis process, and ferric ions that are a nutrient of phytoplankton are supplied into the ocean. As a result, propagation of phytoplankton is promoted, achieving fixation of carbon dioxide gas by phytoplankton.

[0014]

According to the magnesium recovery apparatus of the present invention, there is provided: an electrolysis tank which has an anode and a cathode; a barrier membrane which partitions the interior of the electrolysis tank into an anode-side region containing the anode, and a cathode-side region containing the cathode; a first treatment tank which stores anodic electrolyzed water produced in the anode-side region; a second treatment tank which stores cathodic electrolyzed water produced in the cathode-side region; a power-supply unit which supplies power to the anode and the cathode; an alkaline material input device which inputs alkaline material into the first treatment tank; and a recovery unit which recovers magnesium hydroxide precipitated in the second treatment tank, in which by intermixing wastewater from the first treatment tank and wastewater from the second treatment tank, wastewater is discharged with a pH identical to that of seawater. Consequently, it is possible to recover magnesium from seawater without impact on the environment.

[0015]

In the magnesium recovery apparatus of the present invention, when the power-supply unit has at least one photovoltaic cell, fuel cell, wind power generator, wave power generator, ocean thermal power generator, or solar thermal power generator, it is possible to recover magnesium without impact on the environment.

[0016]

In the magnesium recovery apparatus of the present invention, when the power-supply unit contains a fuel cell which uses hydrogen gas generated on the cathode side, and oxygen gas generated on the anode side, a portion of the power expended in seawater electrolysis is again used in seawater electrolysis. Consequently, energy conservation is achieved.

[0017]

In the magnesium recovery apparatus of the present invention, when the alkaline material inputted from the alkaline material input device is waste concrete, treatment of waste concrete which is an industrial waste product can be concomitantly performed.

[0018]

In the magnesium recovery apparatus of the present invention, when the anode includes iron as a consumable electrode, the consumable electrode dissolves ferric ions, thereby supplying ferric ions, which are a nutrient of phytoplankton, into the ocean. As a result, the excellent effects are obtained that propagation of phytoplankton is promoted, and fixation of carbon dioxide gas by phytoplankton is achieved.

Brief Description of Drawings

[0019]

FIG. 1 is a schematic view of an embodiment of the present invention.

FIG. 2 is a graph which shows cathode current density and the precipitation ratio of CaCO_3 and $\text{Mg}(\text{OH})_2$ in the embodiment.

FIG. 3 is a block diagram which shows material balance in the embodiment of the present invention.

FIG. 4 is a schematic block diagram which shows the magnesium recovery

apparatus of an embodiment of the present invention.

Description of Embodiments

[0020]

5 Embodiments of the present invention are described below with reference to drawings.

[0021]

First, the principles of an embodiment of the present invention are described in FIG. 1.

10 [0022]

In FIG. 1, 1 indicates an electrolysis tank, 2 indicates a first treatment tank, and 3 indicates a second treatment tank.

[0023]

15 The electrolysis tank 1 has an electrolytic treatment container 4 made of corrosion-resistant material such as stainless steel, and the electrolytic treatment container 4 has an inlet 5 at the upstream end, and an outlet 6 at the downstream end. Seawater 7, which flows in from the inlet 5, runs uniformly through the interior of the electrolytic treatment container 4, and is discharged from the outlet 6.

[0024]

20 Various methods may be adopted as a method of forming the flow of the seawater 7. For example, the electrolytic treatment container 4 may be submerged in water to utilize ocean current, and have the seawater 7 flow through the interior of the electrolytic treatment container 4; or a screw or the like may be provided in the inlet 5 to create water flow by rotating this screw by a motor; or the seawater 7 may be taken in by
25 a pump or the like, and supplied to the inlet 5.

[0025]

A barrier membrane 8 is provided inside the electrolytic treatment container 4 in the flow direction of the seawater. The barrier membrane 8 partitions the interior of the electrolytic treatment container 4 in two, with the result that a flow of the seawater 7
5 separated by the barrier membrane 8 is formed inside the electrolytic treatment container 4.

[0026]

The barrier membrane 8 uses a material and structure through which electric current passes and which prevent or inhibit intermixture of the separated streams. For
10 example, one may use unglazed plates in tile form laid out in rows, or porous sheets or the like made of synthetic resin.

[0027]

In the case where the interior of the electrolytic treatment container 4 is partitioned by the barrier membrane 8, various formats are conceivable such as vertical
15 partitioning, lateral partitioning, and concentric partitioning, but the following is a description of the case where the interior of the electrolytic treatment container 4 is vertically partitioned by the barrier membrane 8.

[0028]

A positive electrode (anode) 9 is provided along the upper wall surface of the
20 electrolytic treatment container 4, a negative electrode (cathode) 11 is provided along the lower wall surface, and the anode 9 and the cathode 11 are respectively connected to a positive pole and negative pole of a power-supply unit 12. Accordingly, an anode-side region 9a and cathode-side region 11a are formed within the electrolytic treatment
container 4 by partitioning of the interior of the electrolytic treatment container 4 by the
25 barrier membrane 8.

[0029]

The power source of the power-supply unit 12 is optional, but a power supply source utilizing natural energy such as photovoltaic power generation, wind power generation, wave power generation, ocean thermal power generation, and solar thermal power generation, or a fuel cell which has harmless emissions are preferable. A composite device composed of two or more power sources such as photovoltaic power generation, wind power generation, wave power generation, ocean thermal power generation, solar thermal power generation, and a fuel cell may also be used. Furthermore, in the case where power is supplied from an electric power plant, it is also acceptable to utilize nighttime surplus power.

[0030]

As the anode 9, an anode is used in which a soluble metal is inputted as a consumable electrode material 13 into a bucket (consumable electrode storage container) of reticular or porous plates of an insoluble metal such as titanium. Iron is preferable as the inputted consumable electrode material 13. Not only is iron easy to obtain as waste material, but the ferric ions that dissolve serve as nutrients for propagation of phytoplankton. As a result, phytoplankton is propagated by supplying ferric ions to the seawater, and carbon dioxide gas fixation by phytoplankton can also be anticipated.

[0031]

The cathode 11 uses platinized titanium or the like. A hydrogen recovery device 14 is provided in the vicinity of the cathode 11 or opposite the cathode 11, and the hydrogen recovery device 14 recovers hydrogen gas generated on the cathode 11 side. Seawater (anodic electrolyzed water 7a) that flows through the anode 9 side (anode-side region 9a) is directed to the first treatment tank 2, and seawater (cathodic electrolyzed water 7b) that flows through the cathode 11 side (cathode-side region 11a) is directed to

the second treatment tank 3.

[0032]

The first treatment tank 2 has a waste concrete input device 15, and concrete that is waste material is inputted into the first treatment tank 2 by the waste concrete input device 15. The inputted waste concrete is preferably pulverized with a large surface area, and removal of aggregate such as sand, rocks and the like is more preferable.

[0033]

Hydrogen gas recovered in the seawater 7 is supplied as a reducing agent of the fuel cell to the second treatment tank 3. Precipitated $\text{Mg}(\text{OH})_2$ is deposited in the second treatment tank 3, and the deposited $\text{Mg}(\text{OH})_2$ is recovered. The anodic electrolyzed water 7a that flows out from the first treatment tank 2 and the cathodic electrolyzed water 7b that flows out from the second treatment tank 3 are intermixed, and discharged to the ocean after adjustment of pH.

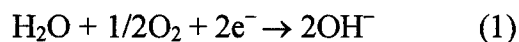
[0034]

The operations of the present embodiment are described below.

[0035]

Electrolysis of seawater occurs by applying voltage between the anode 9 and the cathode 11 to cause energization between the anode 9 and cathode 11, and it is primarily the reactions of the following formulas (1) and (2) that occur on the cathode 11 side.

[0036]



[0037]

Accordingly, the pH of seawater on the cathode side (cathodic electrolyzed water 7b) increases due to generation of OH^- (hydroxy ions), producing CaCO_3 and

Mg(OH)₂, as shown in FIG. 2. In addition, when current-carrying volume per unit area of the cathode 11 is considered as cathode current density Dk (A/m²), the cathode current density Dk and the precipitation ratio of CaCO₃ and Mg(OH)₂ are as shown in FIG. 2. That is, when the cathode current density Dk increases, the precipitation ratio of Mg(OH)₂ increases, and a saturated condition ensues with respect to precipitation of Mg(OH)₂ at the point where cathode current density Dk exceeds 2 (A/m²). Precipitation of CaCO₃ gradually decreases and precipitation of Mg(OH)₂ gradually increases up to a cathode current density Dk of 2 (A/m²). Consequently, by controlling the cathode current density Dk, it becomes possible to control the precipitation ratio of CaCO₃ and Mg(OH)₂, or to selectively precipitate CaCO₃ and Mg(OH)₂.

[0038]

Therefore, by conducting electrolysis with cathode current density Dk set high – that is, by conducting electrolysis of seawater at a cathode current density Dk of 2 [A/m²] or higher in accordance with FIG. 2 – it is possible to have most of the precipitate be Mg(OH)₂.

[0039]

The cathodic electrolyzed water 7b is stored in the second treatment tank 3 in a state where Mg(OH)₂ has precipitated. The precipitated Mg(OH)₂ is deposited in the second treatment tank 3, and the precipitate is recovered by a precipitate recovery means 16.

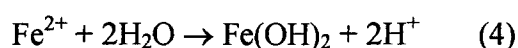
[0040]

In the aforementioned seawater electrolysis process, oxygen gas is generated on the anode 9 side, and hydrogen gas is generated on the cathode 11 side. The generated hydrogen gas is recovered by the hydrogen recovery device 14, and is supplied to the fuel cell as a reducing agent in the case where a fuel cell is used in the power-supply unit 12.

[0041]

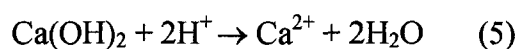
Next, in the case where iron is used as the consumable electrode material 13 on the anode 9 side, the following reactions occur, dissolving the iron. Furthermore, ferrous hydroxide occurs and H^+ is produced by hydrolysis of ferric ions, thereby
 5 lowering the pH of seawater on the anode 9 side (anodic electrolyzed water 7a).

[0042]



[0043]

10 The anodic electrolyzed water 7a which flows into the first treatment tank 2 is turned acidic by $2H^+$. When waste concrete ($Ca(OH)_2$) is inputted into the first treatment tank 2, the acidic seawater is neutralized by the waste concrete according to the following formula.



15 [0044]

In the case where an insoluble metal is used in the anode 9, or when seawater electrolysis is conducted at a high current density, chlorine Cl_2 is generated, and HCl and HClO are generated in conjunction with the generation of Cl_2 . As HCl is strongly acidic, and as HClO is a harmful substance to living creatures, electrolysis is conducted
 20 at a current density that inhibits generation of HCl and HClO to the utmost. However, as stated above, waste concrete ($Ca(OH)_2$) is inputted into the anodic electrolyzed water 7a, whereby the HCl is neutralized by the reaction of:

[0045]



[0046]

The seawater that has been neutralized and treated in the first treatment tank 2 is then intermixed with the seawater discharged from the second treatment tank 3, and released into the ocean. In this case, the pH of the seawater after intermixture is
5 adjusted to 8.0 – that is, to a pH identical to that of seawater – by controlling the amount of concrete to be dissolved in the anodic electrolyzed water 7a and the amount of carbon dioxide gas to be blown into the cathodic electrolyzed water 7b.

[0047]

Therefore, according to the present invention, as recovery of $\text{Mg}(\text{OH})_2$ can be
10 continuously conducted, and as waste concrete is used in the fixation treatment process, treatment of industrial waste material can be conducted in parallel. Furthermore, as the seawater that is discharged after recovery of $\text{Mg}(\text{OH})_2$ has a pH identical to that of natural seawater, there is no environmental impact. As the ferric ions dissolved in the electrolytic process cause propagation of phytoplankton, fixation of carbon dioxide gas is
15 also promoted.

[0048]

As stated above, in the seawater electrolysis process, oxygen gas is generated on the anode 9 side, and hydrogen gas is generated on the cathode 11 side. In the case where a fuel cell is used in the power-supply unit 12, the oxygen gas and the hydrogen
20 gas are supplied to the fuel cell, serving as fuel for power generation.

[0049]

Next, an example of material balance in the foregoing embodiment is described with reference to FIG. 3. In FIG. 3, components identical to those shown in FIG. 1 are given the same reference symbols.

25

[0050]

Electrolytic reaction is varied by varying the cathode current density D_k , and electrolytic reaction is promoted by increasing the cathode current density D_k .

Therefore, it is possible to control pH on the anode 9 side and the cathode 11 side in the $Mg(OH)_2$ recovery treatment process by controlling the cathode current density D_k .

5 [0051]

First, the pH of the cathodic electrolyzed water 7b is set to 10-11, and Ca^{2+} and Mg^{2+} in the seawater are entirely precipitated by electrolysis. At this time, the pH of the anodic electrolyzed water 7a is on the order of 3-4. In order to conduct recovery of $Mg(OH)_2$ efficiently, the cathode current density D_k is set to 2 [A/m^2] or higher.

10 [0052]

Recovery of the $Mg(OH)_2$ that has precipitated in the second treatment tank 3 is then conducted. The pH of the cathodic electrolyzed water 7b that flows out from the second treatment tank 3 is set to 10-11. Waste concrete is inputted into the first treatment tank 2, and the pH of the anodic electrolyzed water 7a that flows out from the first treatment tank 2 is adjusted to 4-5. The pH of the outflowing anodic electrolyzed water 7a is but one example, and the input amount of the aforementioned waste concrete is adjusted so that pH is 8.0-8.2 when the anodic electrolyzed water 7a and the cathodic electrolyzed water 7b are intermixed. By setting the pH of the discharged wastewater to 8.0-8.2, recovery of $Mg(OH)_2$ can be conducted while discharging wastewater without changing the physical properties of the seawater. Accordingly, there is no impact on the environment.

[0053]

By refining the recovered $Mg(OH)_2$, magnesium metal can be produced.

[0054]

25 In the foregoing embodiment, waste concrete is used as the neutralizer of the

anodic electrolyzed water 7a, but any neutralizer is acceptable provided that it is waste material having alkalinity, such as the coal ash produced in thermoelectric power plants.

[0055]

In the foregoing embodiment, seawater electrolysis is conducted while
5 circulating seawater inside the electrolysis tank 1, but it is also acceptable to have a batch system in which on-off valves are respectively provided in the inlet 5 and the outlet 6, seawater electrolysis is conducted in a state where the inlet 5 and the outlet 6 are closed, and the seawater inside the electrolysis tank 1 is replaced after electrolytic treatment.

[0056]

10 FIG. 4 shows an overview of a $\text{Mg}(\text{OH})_2$ recovery apparatus pertaining to an embodiment of the present invention.

[0057]

In FIG. 4, components identical to those shown in FIG. 1 are given the same reference symbols. Moreover, in the embodiment shown in FIG. 4, a fuel cell 18 is
15 shown as the power source.

[0058]

In this apparatus, a hydrogen gas recovery line 21 is provided which recovers hydrogen gas that is generated on the hydrogen recovery device 14 side of the electrolysis tank 1, and which supplies it to the fuel cell 18, and an oxygen gas recovery
20 line 22 is provided which recovers oxygen gas that is generated on the anode 9 side of the electrolysis tank 1, and which supplies it to the fuel cell 18. The hydrogen gas recovery line 21 and the oxygen gas recovery line 22 respectively have gas flow-rate regulation blowers 23 and 24 to regulate the flow rate of the oxygen gas and the hydrogen gas that are supplied to the fuel cell 18.

25 [0059]

The power generated by the fuel cell 18 accumulates in the power-supply unit 12, and the supply of accumulated power is controlled so that a prescribed cathode current density D_k is attained in the cathode 11. Power shortfalls in the amount of power generated by the fuel cell 18 are supplemented by power from photovoltaic power generation, wind power generation, or wave power generation, or by power from electric power plants.

[0060]

A seawater supply line 25, a waste concrete tank 26 (equivalent to the first treatment tank 2), and a recovery tank 27 (equivalent to the second treatment tank 3) are connected to the electrolysis tank 1.

[0061]

Acidic water which is the anodic electrolyzed water 7a is supplied to the waste concrete tank 26, waste concrete is inputted into the waste concrete tank 26, pH is adjusted so that the water is weakly acidic, and the adjusted water is discharged.

[0062]

Alkaline water which is the cathodic electrolyzed water 7b containing $Mg(OH)_2$ is supplied to the recovery tank 27. The $Mg(OH)_2$ that has precipitated in the recovery tank 27 is recovered, and the cathodic electrolyzed water 7b (alkaline water) from which $Mg(OH)_2$ has been removed is discharged from the recovery tank 27.

[0063]

After the acidic water that has been discharged from the waste concrete tank 26 and the alkaline water that has been discharged from the recovery tank 27 are intermixed, discharge is conducted from the recovery apparatus into the ocean. The pH of the wastewater is adjusted by the intermixing of acidic water and alkaline water, with the result that the pH of the wastewater in a state where it is finally released from the

recovery apparatus is identical to the pH of seawater, and there is no impact on the environment.

[0064]

In FIG. 4, 31 indicates a pump which feeds seawater to the electrolysis tank 1,
 5 32 indicates a pump which feeds the cathodic electrolyzed water 7b to the recovery tank
 27, 33 indicates a pump that serves to discharge water from the waste concrete tank 26,
 and 34 indicates a pump that serves to discharge water from the recovery tank 27.

Industrial Applicability

10 [0065]

According to the present invention, it is possible to provide a magnesium
 recovery method and a magnesium recovery apparatus which enable recovery of
 magnesium from seawater while minimizing impact on the environment.

15 Reference Signs List

[0066]

1: electrolysis tank,

2: first treatment tank,

3: second treatment tank,

20 4: electrolytic treatment container,

5: inlet,

7: seawater,

7a: anodic electrolyzed water,

7b: cathodic electrolyzed water,

25 8: barrier film,

9: anode,

9a: anode-side region,

11: cathode,

11a: cathode-side region,

5

12: power-supply unit,

13: consumable electrode material,

14: hydrogen recovery device,

15: waste concrete input device,

16: carbon dioxide gas blower,

10

18: fuel cell,

21: hydrogen gas recovery line,

22: oxygen gas recovery line,

26: waste concrete tank,

27: recovery tank

15

THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. A magnesium recovery method including:
 - electrolyzing seawater;
 - 5 separating anodic electrolyzed water and cathodic electrolyzed water produced by electrolysis of the seawater;
 - inputting alkaline material into the anodic electrolyzed water to adjust pH;
 - precipitating magnesium as magnesium hydroxide in the cathodic electrolyzed water, and recovering the magnesium hydroxide; and
 - 10 intermixing the anodic electrolyzed water after pH adjustment and the cathodic electrolyzed water after recovery of the magnesium hydroxide, and discharging the intermixed water in a state where a pH of the intermixed water is identical to a pH of the seawater.
- 15 2. The magnesium recovery method according to claim 1, wherein the alkaline material is waste concrete.
3. The magnesium recovery method according to claim 1, wherein iron, which is a soluble metal, is used in the anode-side electrode to cause dissolution of ferric ions in the
20 anodic electrolyzed water in the seawater electrolysis process.
4. A magnesium recovery apparatus, including:
 - an electrolysis tank having an anode and a cathode;
 - a barrier film which partitions an interior of the electrolysis tank into an anode-side
25 region containing the anode, and a cathode-side region containing the cathode;
 - a first treatment tank which stores anodic electrolyzed water produced in the anode-side region;
 - a second treatment tank which stores cathodic electrolyzed water produced in the cathode-side region;
 - 30 a power-supply unit which supplies power to the anode and the cathode;
 - an alkaline material input device which inputs alkaline material to the first

treatment tank; and

a recovery unit which recovers magnesium hydroxide precipitated in the second treatment tank,

wherein wastewater from the first treatment tank and wastewater from the second treatment tank are intermixed, and discharged in a state where a pH of the intermixed water is identical to a pH of seawater.

5 5. The magnesium recovery apparatus according to claim 4, wherein the power-supply unit has at least one of photovoltaic cell, fuel cell, wind power generator, wave
10 power generator, ocean thermal power generator, and solar thermal power generator.

6. The magnesium recovery apparatus according to claim 4, wherein the power-supply unit contains a fuel cell which uses hydrogen gas generated on the cathode-side region, and oxygen gas generated on the anode-side region.

15

7. The magnesium recovery apparatus according to claim 4, wherein the alkaline material inputted from the alkaline material input device is waste concrete.

8. The magnesium recovery apparatus according to claim 4, wherein the anode
20 contains iron as a consumable electrode, and the consumable electrode dissolves ferric ions.