Solution to Problem

[0006a] According to a first aspect, there is provided a subsurface soil purification method including: a first step of generating a treated water from which a contaminant in a subsurface soil included in groundwater pumped from a water pumping well provided in the ground has been removed in a water treatment unit, warming a cleaning liquid generated from the treated water to a higher temperature than a groundwater temperature, and feeding the cleaning liquid into the subsurface soil by injecting the cleaning liquid into an injection well provided in the ground at a position away from the water pumping well for separating the contaminant in the subsurface soil from the subsurface soil, a second step of pumping groundwater containing the cleaning liquid, in which the contaminant separated from the subsurface soil has been dissolved, from the water pumping well, and a third step, which is executed after the first step or the second step, of generating the treated water in the water treatment unit, warming an activator liquid generated from the treated water to a higher temperature than the groundwater temperature, feeding the activator liquid into the subsurface soil by injecting the activator liquid into the injection well for stimulating decomposer microorganisms that decompose the contaminant in the subsurface soil, and forcing air into the injection well, wherein forcing air into the injection well comprises feeding the air into the subsurface soil from a position in the injection well that is lower than a position in the injection well for feeding the activator liquid.

[0006b] According to a second aspect, there is provided a subsurface soil purification method including: a first step of generating a treated water from which a contaminant in a subsurface soil included in groundwater pumped from a water pumping well provided in the ground has been removed in a water treatment unit, warming a cleaning liquid generated from the treated water to a higher temperature than a groundwater temperature, and feeding the cleaning liquid into the subsurface soil by injecting the cleaning liquid into an injection well provided in the ground at a position away from the water pumping well for separating the contaminant in the subsurface soil from the subsurface soil, a second step of pumping groundwater containing the cleaning liquid, in which the contaminant separated from the subsurface soil has been dissolved, from the water pumping well, and a third step, which is executed after the first step or the second step, of generating the treated water in the water treatment unit, warming an activator liquid generated from the treated water and decomposer microorganisms that decompose the contaminant in the subsurface soil to a higher temperature than the groundwater temperature, feeding the activator liquid into the subsurface soil by injecting the activator liquid into the injection well for stimulating the decomposer microorganisms in the

subsurface soil, and forcing air into the injection well, wherein forcing air into the injection well comprises feeding the air into the subsurface soil from a position in the injection well that is lower than a position in the injection well for feeding the activator liquid.

[0006c] According to a third aspect, there is provided a subsurface soil purification method comprising: a first step of generating a treated water from which a contaminant in a subsurface soil included in groundwater pumped from a water pumping well provided in the ground has been removed in a water treatment unit, warming a cleaning liquid generated from the treated water to a higher temperature than a groundwater temperature, and feeding the cleaning liquid into the subsurface soil by injecting the cleaning liquid into an injection well provided in the ground at a position away from the water pumping well for separating the contaminant in the subsurface soil from the subsurface soil, a second step of pumping groundwater containing the cleaning liquid, in which the contaminant separated from the subsurface soil has been dissolved, from the water pumping well, and a third step, which is executed after the first step or the second step, of generating the treated water in the water treatment unit, infusing air bubbles in an activator liquid generated from the treated water, warming the activator liquid to a higher temperature than the groundwater temperature, and feeding the activator liquid into the subsurface soil by injecting the activator liquid into the injection well for stimulating decomposer microorganisms in the subsurface soil.

[0006d] According to a fourth aspect, there is provided a subsurface soil purification method including: a first step of generating a treated water from which a contaminant in a subsurface soil included in groundwater pumped from a water pumping well provided in the ground has been removed in a water treatment unit, warming a cleaning liquid generated from the treated water to a higher temperature than a groundwater temperature, and feeding the cleaning liquid into the subsurface soil by injecting the cleaning liquid into an injection well provided in the ground at a position away from the water pumping well for separating the contaminant in the subsurface soil from the subsurface soil, a second step of pumping groundwater containing the cleaning liquid, in which the contaminant separated from the subsurface soil has been dissolved, from the water pumping well, and a third step, which is executed after the first step or the second step, of generating the treated water in the water treatment unit, infusing air bubbles in an activator liquid generated from the treated water, warming the activator liquid and decomposer microorganisms that decompose the contaminant in the subsurface soil to a higher temperature than the groundwater temperature, and feeding the activator liquid and the decomposer microorganisms into the subsurface soil by injecting the activator liquid and the

decomposer microorganisms into the injection well for stimulating the decomposer microorganisms in the subsurface soil.

[0006e] According to a fifth aspect, there is provided a subsurface soil purification method comprising: a first step of generating a treated water from which a contaminant in a subsurface soil included in groundwater pumped from a water pumping well provided in the ground has been removed in a water treatment unit, warming a cleaning liquid generated from the treated water to a higher temperature than a groundwater temperature, and feeding the cleaning liquid into the subsurface soil by injecting the cleaning liquid into an injection well provided in the ground at a position away from the water pumping well for separating the contaminant in the subsurface soil from the subsurface soil, a second step of pumping groundwater containing the cleaning liquid, in which the contaminant separated from the subsurface soil has been dissolved, from the water pumping well, and a third step, which is executed after the first step or the second step, of generating the treated water in the water treatment unit, warming a purification liquid generated from the treated water to a higher temperature than the groundwater temperature, feeding the purification liquid into the subsurface soil by injecting the purification liquid into the injection well for decomposing the contaminant in the subsurface soil, and forcing air into the injection well, wherein forcing air into the injection well comprises feeding the air into the subsurface soil from a position in the injection well that is lower than a position in the injection well for feeding the purification liquid.

[0006e] According to a sixth aspect, there is provided a subsurface soil purification method including: a first step of generating a treated water from which a contaminant in a subsurface soil included in groundwater pumped from a water pumping well provided in the ground has been removed in a water treatment unit, warming a cleaning liquid generated from the treated water to a higher temperature than a groundwater temperature, and feeding the cleaning liquid into the subsurface soil by injecting the cleaning liquid into an injection well provided in the ground at a position away from the water pumping well for separating the contaminant in the subsurface soil from the subsurface soil, a second step of pumping groundwater containing the cleaning liquid, in which the contaminant separated from the subsurface soil has been dissolved, from the water pumping well, and a third step, which is executed after the first step or the second step, of generating the treated water in the water treatment unit, infusing air bubbles in a purification liquid generated from the treated water, warming the purification liquid, which decomposes the contaminant in the subsurface soil, to a higher temperature than the groundwater temperature, and feeding the purification liquid into the subsurface soil by

injecting the purification liquid into the injection well for decomposing the contaminant in the subsurface soil.

[0007] In a first approach, a subsurface soil purification method includes: warming an activator liquid, for stimulating decomposer microorganisms that decompose a contaminant in subsurface soil, to a higher temperature than a groundwater temperature, and feeding the activator liquid into the subsurface soil by injecting the activator liquid into an in-ground injection well; warming an activator liquid, for stimulating decomposer microorganisms that decompose a contaminant in subsurface soil, the decomposer microorganisms being infused in the activator liquid, to a higher temperature than a groundwater temperature, and feeding the activator liquid into the subsurface soil by injecting the activator liquid into an in-ground injection well, or warming a purification liquid for decomposing a contaminant in subsurface soil, to a higher temperature than a groundwater temperature, and feeding the purification liquid into the subsurface soil by injecting the purification liquid into an in-ground injection well. The subsurface soil purification method also includes forcing air into the injection well, and feeding the air into the subsurface soil from a position in the injection well that is lower than a position in the injection well for feed-in of the activator liquid or the purification liquid.

[0008] In the first approach, the specific gravity of the activator liquid or the purification liquid is made less than the specific gravity of the groundwater by warming the activator liquid or the purification liquid. The activator liquid or the purification liquid is accordingly caused to migrate upward in the subsurface soil, enabling a lot of the activator liquid or the purification liquid to be spread to the proximity band above the groundwater surface in the subsurface soil.

[0009] Moreover, due to the air being fed from a position on the injection well lower than the position on the injection well for feed-in of the activator liquid or the purification liquid, the activator liquid or the purification liquid is caused to migrate upward in the subsurface soil by the air, enabling even more of the activator liquid or the purification liquid to be spread to the proximity band above the groundwater surface in the subsurface soil.

[0010] This enables the efficiency of purifying subsurface soil contaminated with a contaminant having a density lower than that of water, such as an oil, benzene, or the like, to be raised.

[0011] In a second approach, a subsurface soil purification method includes: warming an activator liquid, for stimulating decomposer microorganisms that decompose a contaminant in subsurface soil, air bubbles being infused in the activator liquid, to a higher temperature than a groundwater temperature, and feeding the activator liquid into the subsurface soil by

injecting the activator liquid into an in-ground injection well; warming an activator liquid, for stimulating decomposer microorganisms that decompose a contaminant in subsurface soil, both air bubbles and the decomposer microorganisms being infused in the activator liquid, to a higher temperature than a groundwater temperature, and feeding the activator liquid into the subsurface soil by injecting the activator liquid into an in-ground injection well; or warming a purification liquid, for decomposing a contaminant in subsurface soil, air bubbles being infused in the purification liquid, to a higher temperature than a groundwater temperature, and feeding the purification liquid into the subsurface soil by injecting the purification liquid into an in-ground injection well.

[0012] In the second approach, the specific gravity of the activator liquid or the purification liquid is made less than the specific gravity of the groundwater by warming the activator liquid or the purification liquid. The activator liquid or the purification liquid is accordingly caused to migrate upward in the subsurface soil, enabling a lot of the activator liquid or the purification liquid to be spread to a proximity band above the groundwater surface in the subsurface soil.

[0013] Moreover, by feeding the activator liquid or the purification liquid infused with air bubbles into the subsurface soil by injection into the injection well, the activator liquid or the purification liquid is caused to migrate upward in the subsurface soil by the air bubbles, enabling more of the activator liquid or the purification liquid to be spread to a proximity band above the groundwater surface in the subsurface soil.

[0014] This enables the efficiency of purifying subsurface soil contaminated with a contaminant having a density lower than that of water, such as an oil, benzene, or the like, to be raised.

[0015] In a third approach, a subsurface soil purification method of the first or second approaches further includes, prior to performing the warming or forcing processes of the first or second approaches, warming a cleaning liquid, for separating the contaminant from the subsurface soil, to a higher temperature than a groundwater temperature, feeding the cleaning liquid into the subsurface soil by injecting the cleaning liquid into the injection well, and pumping groundwater containing the cleaning liquid, in which the contaminant separated from the subsurface soil has been dissolved, from a water pumping well provided in the ground at a position away from the injection well.

[0016] In the third approach, a contaminant that is adhered to soil particles in the subsurface soil can be separated from the subsurface soil by the cleaning liquid. Pumping the groundwater containing the cleaning liquid having the contaminant separated

CLAIMS

1. A subsurface soil purification method comprising:

a first step of generating a treated water from which a contaminant in a subsurface soil included in groundwater pumped from a water pumping well provided in the ground has been removed in a water treatment unit, warming a cleaning liquid generated from the treated water to a higher temperature than a groundwater temperature, and feeding the cleaning liquid into the subsurface soil by injecting the cleaning liquid into an injection well provided in the ground at a position away from the water pumping well for separating the contaminant in the subsurface soil from the subsurface soil,

a second step of pumping groundwater containing the cleaning liquid, in which the contaminant separated from the subsurface soil has been dissolved, from the water pumping well, and

a third step, which is executed after the first step or the second step, of generating the treated water in the water treatment unit, warming an activator liquid generated from the treated water to a higher temperature than the groundwater temperature, feeding the activator liquid into the subsurface soil by injecting the activator liquid into the injection well for stimulating decomposer microorganisms that decompose the contaminant in the subsurface soil, and forcing air into the injection well,

wherein forcing air into the injection well comprises feeding the air into the subsurface soil from a position in the injection well that is lower than a position in the injection well for feeding the activator liquid.

2. A subsurface soil purification method comprising:

a first step of generating a treated water from which a contaminant in a subsurface soil included in groundwater pumped from a water pumping well provided in the ground has been removed in a water treatment unit, warming a cleaning liquid generated from the treated water to a higher temperature than a groundwater temperature, and feeding the cleaning liquid into the subsurface soil by injecting the cleaning liquid into an injection well provided in the ground at a position away from the water pumping well for separating the contaminant in the subsurface soil from the subsurface soil,

a second step of pumping groundwater containing the cleaning liquid, in which the contaminant separated from the subsurface soil has been dissolved, from the water pumping well, and

a third step, which is executed after the first step or the second step, of generating the treated water in the water treatment unit, warming an activator liquid generated from the treated water and decomposer microorganisms that decompose the contaminant in the subsurface soil to a higher temperature than the groundwater temperature, feeding the activator liquid into the subsurface soil by injecting the activator liquid into the injection well for stimulating the decomposer microorganisms in the subsurface soil, and forcing air into the injection well,

wherein forcing air into the injection well comprises feeding the air into the subsurface soil from a position in the injection well that is lower than a position in the injection well for feeding the activator liquid.

3. A subsurface soil purification method comprising:

a first step of generating a treated water from which a contaminant in a subsurface soil included in groundwater pumped from a water pumping well provided in the ground has been removed in a water treatment unit, warming a cleaning liquid generated from the treated water to a higher temperature than a groundwater temperature, and feeding the cleaning liquid into the subsurface soil by injecting the cleaning liquid into an injection well provided in the ground at a position away from the water pumping well for separating the contaminant in the subsurface soil from the subsurface soil,

a second step of pumping groundwater containing the cleaning liquid, in which the contaminant separated from the subsurface soil has been dissolved, from the water pumping well, and

a third step, which is executed after the first step or the second step, of generating the treated water in the water treatment unit, infusing air bubbles in an activator liquid generated from the treated water, warming the activator liquid to a higher temperature than the groundwater temperature, and feeding the activator liquid into the subsurface soil by injecting the activator liquid into the injection well for stimulating decomposer microorganisms in the subsurface soil.

4. A subsurface soil purification method comprising:

a first step of generating a treated water from which a contaminant in a subsurface soil included in groundwater pumped from a water pumping well provided in the ground has been removed in a water treatment unit, warming a cleaning liquid generated from the treated water to a higher temperature than a groundwater temperature, and feeding the cleaning liquid into the subsurface soil by injecting the cleaning liquid into an injection well provided in the ground at a position away from the water pumping well for separating the contaminant in the subsurface soil from the subsurface soil,

a second step of pumping groundwater containing the cleaning liquid, in which the contaminant separated from the subsurface soil has been dissolved, from the water pumping well, and

a third step, which is executed after the first step or the second step, of generating the treated water in the water treatment unit, infusing air bubbles in an activator liquid generated from the treated water, warming the activator liquid and decomposer microorganisms that decompose the contaminant in the subsurface soil to a higher temperature than the groundwater temperature, and feeding the activator liquid and the decomposer microorganisms into the subsurface soil by injecting the activator liquid and the decomposer microorganisms into the injection well for stimulating the decomposer microorganisms in the subsurface soil.

5. A subsurface soil purification method comprising:

a first step of generating a treated water from which a contaminant in a subsurface soil included in groundwater pumped from a water pumping well provided in the ground has been removed in a water treatment unit, warming a cleaning liquid generated from the treated water to a higher temperature than a groundwater temperature, and feeding the cleaning liquid into the subsurface soil by injecting the cleaning liquid into an injection well provided in the ground at a position away from the water pumping well for separating the contaminant in the subsurface soil from the subsurface soil,

a second step of pumping groundwater containing the cleaning liquid, in which the contaminant separated from the subsurface soil has been dissolved, from the water pumping well, and

a third step, which is executed after the first step or the second step, of generating the treated water in the water treatment unit, warming a purification liquid generated from the treated water to a higher temperature than the groundwater temperature, feeding the purification liquid into the subsurface soil by injecting the purification liquid into the injection

well for decomposing the contaminant in the subsurface soil, and forcing air into the injection well,

wherein forcing air into the injection well comprises feeding the air into the subsurface soil from a position in the injection well that is lower than a position in the injection well for feeding the purification liquid.

6. A subsurface soil purification method comprising:

a first step of generating a treated water from which a contaminant in a subsurface soil included in groundwater pumped from a water pumping well provided in the ground has been removed in a water treatment unit, warming a cleaning liquid generated from the treated water to a higher temperature than a groundwater temperature, and feeding the cleaning liquid into the subsurface soil by injecting the cleaning liquid into an injection well provided in the ground at a position away from the water pumping well for separating the contaminant in the subsurface soil from the subsurface soil,

a second step of pumping groundwater containing the cleaning liquid, in which the contaminant separated from the subsurface soil has been dissolved, from the water pumping well, and

a third step, which is executed after the first step or the second step, of generating the treated water in the water treatment unit, infusing air bubbles in a purification liquid generated from the treated water, warming the purification liquid, which decomposes the contaminant in the subsurface soil, to a higher temperature than the groundwater temperature, and feeding the purification liquid into the subsurface soil by injecting the purification liquid into the injection well for decomposing the contaminant in the subsurface soil.

7. The subsurface soil purification method of any one of claim 1 through claim 4,wherein the cleaning liquid is warmed to a temperature of from 25 ℃ to 60 ℃, and the activator liquid is warmed to a temperature of from 20 ℃ to 35 ℃.

8. The subsurface soil purification method of claim 5 or claim 6, wherein the purification liquid is generated by mixing iron-based slurry with the treated water.

9. The subsurface soil purification method of any one of claim 1 through claim 8, wherein the third step is executed after the second step, and the water treatment unit removes

the contaminant from the groundwater pumped from the water pumping well to generate the treated water.