DESCRIPTION

CONTAMINATED SOIL PURIFICATION METHOD

Technical Field

[0001] The present disclosure relates to a contaminated soil purification method.

Background Art

[0002] Japanese Patent Application Laid-Open (JP-A) No. 2005-52733 discloses a purification unit in which a liquid to which an oil decomposition accelerator has been added is injected into oil-contaminated soil. The injected liquid permeates the contaminated soil and is pumped up from a water-collection well. The turbidity of the recovered liquid that has been pumped up is checked by a turbidity meter or by visual inspection by an operator, and the addition amount of the oil decomposition accelerator for injection into the contaminated soil is regulated.

SUMMARY OF INVENTION

Technical Problem

[0003] In the purification unit disclosed in JP-A No. 2005-52733, checking of the recovered liquid and regulation of the addition amount of oil decomposition accelerator for injection into the contaminated soil needs to be performed by a manual operation on each occasion and so takes effort to perform.

[0004] In consideration of the above circumstances, an object of the present disclosure is to provide a contaminated soil purification method enabling an operation to purify contaminated soil to be performed with less manpower.

Solution to Problem

[0004a] In accordance with a first aspect of the present disclosure, there is provided a contaminated soil purification method for decomposing a contaminant in contaminated soil, the contaminated soil purification method comprising: injecting, into contaminated soil through a first well adapted for water injection, an injection liquid comprising a first agent; measuring a concentration of the first agent in groundwater in a second well, the second well being provided at a location spaced apart from the first well; based on the concentration of the first agent that has been measured, automatically controlling an addition amount of the first agent to the injection liquid or automatically controlling a pumping amount of water from the second well; and determining a time at which a groundwater temperature of the groundwater in the second well will reach a target temperature, using a management function, wherein the

management function calculates, at regular elapsed time intervals, a predicted temperature of the groundwater, based on: an initial temperature of the groundwater in the second well prior to starting injection of the injection liquid, an injection temperature of the injection liquid injected into the contaminated soil through the first well, an elapsed time from a start of injection of the injection liquid, and soil properties of the contaminated soil, wherein the determined time at which the groundwater temperature of the groundwater in the second well will reach a target temperature is used for automatically controlling the pumping amount of water from the second well or a warming amount of the injection liquid.

[0004b] In accordance with a second aspect of the present disclosure, there is provided a contaminated soil purification method for decomposing a contaminant in contaminated soil, the contaminated soil purification method comprising: injecting, into contaminated soil through a first well adapted for water injection, an injection liquid comprising a first agent; measuring a concentration of the first agent in groundwater in a second well, the second well being provided at a location spaced apart from the first well; based on the concentration of the first agent that has been measured, automatically controlling an addition amount of the first agent to the injection liquid or automatically controlling a pumping amount of water from the second well; and determining a time at which a groundwater temperature of the groundwater in the second well will reach a target temperature, using a management function, wherein the management function calculates, at regular elapsed time intervals, a predicted temperature of the groundwater, based on: an initial temperature of the groundwater in the second well prior to starting injection of the injection liquid, an injection temperature of the injection liquid injected into the contaminated soil through the first well, an elapsed time from a start of injection of the injection liquid, and soil properties of the contaminated soil, wherein the determined time at which the groundwater temperature of the groundwater in the second well will reach a target temperature is used for automatically controlling the pumping amount of water from the second well or a warming amount of the injection liquid.

[0005] A first approach of the present disclosure is a contaminated soil purification method for decomposing a contaminant in contaminated soil. The contaminated soil purification method includes: a process of injecting, into contaminated soil through a water injection well, an injection liquid containing a purification agent to decompose a contaminant or an activator to stimulate biological decomposition by the purification agent; a process of measuring a concentration of the purification agent or the activator in groundwater in an observation well

or in a pumping well, the observation well or the pumping well being provided at a location spaced apart from the water injection well; and a process of, based on the concentration that has been measured, automatically controlling an addition amount of the purification agent or the activator to the injection liquid or automatically controlling a pumping amount of water from the pumping well.

[0006] In the contaminated soil purification method of the first approach of the present disclosure, the in-situ concentration of the purification agent or the activator in the groundwater is measured in the observation well or the water pumping well. The addition amount of the purification agent or the activator or the pumping rate of water from the water pumping well is then automatically controlled based on the concentration that has been measured. For example, if the concentration that has been measured (namely, the concentration of the activator in the contaminated soil) is lower than a target concentration, the addition amount of the activator to the injection liquid is automatically increased. Or the pumping rate is automatically increased to raise the suction force on the groundwater so as to promote permeation of the activator into the contaminated soil. The concentration of the activator is thereby regulated in a timely manner so as to enable efficient purification of the contaminated soil.

[0007] A contaminated soil purification method of a second approach of the present disclosure further comprises, predicting a time at which the concentration of the purification agent or the activator in the groundwater in the observation well or in the pumping well will reach a target concentration, or a time at which a groundwater temperature of the groundwater in the observation well or in the pumping well will reach a target temperature, using a management function. The management function calculates, at regular elapsed time intervals, a predicted concentration of the purification agent or the activator in the groundwater, or a predicted temperature of the groundwater, based on an initial concentration of the purification agent or the activator in the groundwater, or an initial temperature of the groundwater in the observation well or in the pumping well, prior to starting injection of the injection liquid, based on an injection concentration of the purification agent or the activator in the injection liquid or an injection temperature of the injection liquid injected into the contaminated soil through the water injection well, based on an elapsed time from a start of injection of the injection liquid, and based on inherent soil properties of the contaminated soil.

[0008] In the contaminated soil purification method of the second approach of the present disclosure, the predicted concentration of the purification agent or the activator in the groundwater in the observation well or the water pumping well, or the predicted temperature of the groundwater, is calculated at regular elapsed time intervals using the management

function.

[0009] The management function is able to calculate the predicted concentration of the purification agent or the activator in the groundwater or the predicted temperature of the groundwater at the regular elapsed time intervals based on the initial concentration of the purification agent or the activator in the groundwater or the initial temperature of the groundwater in the observation well or in the water pumping well prior to starting injection of the injection liquid, based on the injection concentration of the purification agent or the activator in the injection liquid or the injection temperature of the injection liquid, based on the elapsed time since the start of injection of the injection liquid, and based on the inherent soil properties of the contaminated soil.

[0010] Namely, the purification of the contaminated soil can be executed systematically by calculating the time required for the concentration of the purification agent or the activator in the groundwater in the contaminated soil or the temperature of the groundwater to reach the target value.

[0011] In the contaminated soil purification method of a third approach of the present disclosure, the management function is corrected, such that the predicted concentration or the predicted temperature calculated using the management function approximates to an actual measured concentration of the purification agent or the activator in the groundwater or an actual measured temperature of the groundwater in the observation well or in the pumping well. The management function is corrected by replacing the initial concentration or the initial temperature with a concentration of the purification agent or the activator in the groundwater or a temperature of the groundwater in the observation well or in the pumping well after a predetermined time has elapsed, and changing the injection concentration or the injection temperature.

[0012] In the contaminated soil purification method of the third approach of the present disclosure, the injection concentration or the injection temperature of the injection liquid is changed, the management function is also corrected based on the injection concentration or the injection temperature after the change, and the initial concentration or the initial temperature in the management function are replaced with the concentration or the temperature of the groundwater after the predetermined time has elapsed. . The difference between the predicted concentration calculated by the management function and the actual measured concentration or the difference between the predicted temperature calculated by the management function and the actual measured temperature is thereby reduced, enabling the prediction accuracy of the management function to be raised.

[0013] Raising the prediction accuracy of the management function enables an injection

liquid having an appropriate amount of the purification agent or the activator added thereto, or an injection liquid having an appropriate temperature, to be injected into the contaminated soil. The purification agent or the activator in the contaminated soil can thereby be suppressed from becoming excessive or insufficient.

Advantageous Effects of Invention

[0014] The contaminated soil purification method according to the present disclosure enables an operation to purify contaminated soil to be performed with less manpower.

BRIEF DESCRIPTION OF DRAWINGS

[0015] Fig. 1A is a plan view illustrating an overall configuration of a contaminated soil purification system according to a first exemplary embodiment of the present disclosure.

Fig. 1B is a vertical cross-section illustrating an overall configuration of a contaminated soil purification system according to the first exemplary embodiment of the present disclosure.

Fig. 2 is a flowchart illustrating a soil purification method of a contaminated soil purification system according to the first exemplary embodiment of the present disclosure.

Fig. 3 is a graph illustrating a management function of a contaminated soil purification system according to a second exemplary embodiment of the present disclosure.

Fig. 4 is a flowchart illustrating a soil purification method of a contaminated soil purification system according to a third exemplary embodiment of the present disclosure.

Fig. 5 is a graph illustrating management functions before and after correction and an actual measured concentration curve in a contaminated soil purification system according to the third exemplary embodiment of the present disclosure.

Fig. 6 is a flowchart illustrating a soil purification method of a contaminated soil purification system according to a fourth exemplary embodiment of the present disclosure.

Fig. 7 is a graph illustrating a soil purification method of stopping and restarting injection of an injection liquid into subsurface soil in a contaminated soil purification system according to the fourth exemplary embodiment of the present disclosure.

Fig. 8 is a flowchart illustrating a modified example of a soil purification method of a contaminated soil purification system according to the first exemplary embodiment of the present disclosure.

Fig. 9 is a plan view illustrating a modified example in which two types of contaminated soil with different contaminant concentrations are purified in a contaminated soil purification system according to the second exemplary embodiment of the present disclosure.

Fig. 10 is a graph illustrating two management functions employed in cases in which two types of contaminated soil with different contaminant concentrations are purified in a contaminated soil purification system according to the second exemplary embodiment of the present disclosure.

embodiment employs the configuration and purification method of the contaminated soil purification system 20 according to the first exemplary embodiment, and additionally employs a management function, described below, to predict a time at which the concentration of the purification agent or activator in the groundwater in the subsurface soil 10 will reach the target concentration.

[0054] Management Function

In Fig. 3, a management function f (t), representing a relationship between elapsed time t from the start of injection of the injection liquid into the subsurface soil 10 and a predicted concentration C of the groundwater in the observation wells 26, is illustrated by a solid line. For example, the predicted concentration at a time t1 is a predicted concentration C1.

[0055] The management function f (t) is represented by the following Equation.

[0056] $f(t) = (A - D) / [1 + G(B / t)^{G}] + D$ ... Equation 1

A: concentration of purification agent or activator in injection liquid

B: constant determined by soil properties X of subsurface soil

G: constant determined by soil properties Y of subsurface soil

D: concentration of purification agent or activator in groundwater prior to injection liquid injection

t: elapsed time since start of injection liquid injection

[0057] The constants B, G in Equation 1 are constants determined by the soil properties X, Y of the subsurface soil, and are decided based on a soil survey carried out ahead of purifying the contaminated soil E. The factors employed in the soil survey used to decide the constants B, G includes, for example, the permeability coefficient of the subsurface soil and the soil particle size.

[0058] Operation and Advantageous Effects

In the contaminated soil purification system according to the second exemplary embodiment, the management function f (t) represented by Equation 1 is employed to calculate the predicted concentration of the groundwater in the observation wells 26 based on the concentration A of the purification agent or activator in the injection liquid injected to the water injection wells 24 at step S90 in Fig. 2, the concentration D of the purification agent or activator in the groundwater in the observation wells 26 prior to injecting the injection liquid, the constants B, G that are determined by the soil properties of the subsurface soil, and the elapsed time t since the start of injection of the injection liquid into the subsurface soil 10.

[0059] This enables prediction of a time tE at which the concentration of the purification agent or activator in the groundwater in the observation wells 26 will reach the target

actual measured temperature has been determined to be outside of the preset permissible values. "Convergence value determination" is performed at step S114 to determine whether the actual measured concentration and the actual measured temperature are stopping rising. In cases in which at least one out of the actual measured concentration and the actual measured temperature is determined to be stopping rising, at least one out of "concentration regulation" or "temperature regulation" is performed at step S124 (namely, factor that was determined to be stopping rising at step S114 is regulated). At step S125, at least one out of the "management function to predict the concentration of the purification agent or the activator in the groundwater" or the "management function to predict the groundwater temperature" (namely, the management function relating to the concentration or the temperature regulated at step S124) is corrected.

[0099] Operation and Advantageous Effects

In the contaminated soil purification system according to the third exemplary embodiment, the management function is corrected in response to disparity between the values predicted by the management function and the actual measured values.

[0100] This thereby enables the prediction accuracy of the management function to be improved. It is accordingly possible to suppress injection of injection liquid containing purification agent or activator at an excessive concentration into the subsurface soil, and to suppress overheating of the injection liquid. Accordingly, wasted resources and energy can be reduced. Moreover, an insufficient amount of purification agent or activator contained in the injection liquid, and insufficient warmth of the injection liquid, can also be suppressed. This thereby enables the soil purification performance to be maintained.

[0101] Fourth Exemplary Embodiment

As illustrated in Fig. 6, in a fourth exemplary embodiment, at step S114, in cases in which the actual measured concentration continues rising without stopping prior to reaching the target concentration range, processing proceeds to step S120 without returning to step S100-2.

[0102] At the steps subsequent to step S120, operation of the contaminated soil purification system is automatically stopped and automatically restarted in order to maintain the concentration of the purification agent or activator in the groundwater in the target concentration range.

[0103] More specifically, first, "upper limit value determination" is performed at step S120. In the upper limit value determination, determination is made as to whether or not the actual measured concentrations have reached a preset upper limit value. In the example illustrated in Fig. 7, the preset upper limit value is an upper concentration limit C3 of the target

CLAIMS

1. A contaminated soil purification method for decomposing a contaminant in contaminated soil, the contaminated soil purification method comprising:

injecting, into contaminated soil through a first well adapted for water injection, an injection liquid comprising a first agent;

measuring a concentration of the first agent in groundwater in a second well, the second well being provided at a location spaced apart from the first well;

based on the concentration of the first agent that has been measured, automatically controlling an addition amount of the first agent to the injection liquid or automatically controlling a pumping amount of water from the second well; and

determining a first time at which the concentration of the first agent in the groundwater in the second well will reach a target concentration, using a management function,

wherein the management function calculates, at regular elapsed time intervals, a predicted concentration of the first agent in the groundwater, based on:

an initial concentration of the first agent in the groundwater prior to starting injection of the injection liquid,

an injection concentration of the first agent in the injection liquid,

a first elapsed time from a start of injection of the injection liquid, and

soil properties of the contaminated soil,

wherein the first time is used for automatically controlling the addition amount of the first agent to the injection liquid or automatically controlling the pumping amount of water from the second well.

2. The contaminated soil purification method of Claim 1, wherein the first agent comprises a purification agent to decompose a contaminant.

3. The contaminated soil purification method of Claim 1, wherein the first agent comprises an activator to stimulate biological decomposition by a purification agent to decompose a contaminant.

4. The contaminated soil purification method of Claim 1, wherein the second well is an

observation well or a pumping well.

5. A contaminated soil purification method for decomposing a contaminant in contaminated soil, the contaminated soil purification method comprising:

injecting, into contaminated soil through a first well adapted for water injection, an injection liquid comprising a first agent;

measuring a concentration of the first agent in groundwater in a second well, the second well being provided at a location spaced apart from the first well;

based on the concentration of the first agent that has been measured, automatically controlling an addition amount of the first agent to the injection liquid or automatically controlling a pumping amount of water from the second well; and

determining a time at which a groundwater temperature of the groundwater in the second well will reach a target temperature, using a management function,

wherein the management function calculates, at regular elapsed time intervals, a predicted temperature of the groundwater, based on:

an initial temperature of the groundwater in the second well prior to starting injection of the injection liquid,

an injection temperature of the injection liquid injected into the contaminated soil through the first well,

an elapsed time from a start of injection of the injection liquid, and

soil properties of the contaminated soil,

wherein the determined time at which the groundwater temperature of the groundwater in the second well will reach a target temperature is used for automatically controlling the pumping amount of water from the second well or a warming amount of the injection liquid.

6. The contaminated soil purification method of Claim 1, further comprising:

determining a second time at which a groundwater temperature of the groundwater in the second well will reach a target temperature, using the management function,

wherein the management function calculates, at regular elapsed time intervals, a predicted temperature of the groundwater, based on:

an initial temperature of the groundwater in the second well, prior to starting injection of the injection liquid,

an injection temperature of the injection liquid injected into the contaminated soil through the first well,

a second elapsed time from the start of injection of the injection liquid, and

soil properties of the contaminated soil,

wherein the second time is used for automatically controlling the pumping amount of water from the second well or a warming amount of the injection liquid.

7. The contaminated soil purification method of Claim 1, wherein the soil properties of the contaminated soil is selected from the group consisting of a permeability coefficient and a soil particle size.

8. The contaminated soil purification method of Claim 5, wherein the soil properties of the contaminated soil is selected from the group consisting of a permeability coefficient and a soil particle size.

9. The contaminated soil purification method of Claim 6, wherein the soil properties of the contaminated soil is selected from the group consisting of a permeability coefficient and a soil particle size.

10. The contaminated soil purification method of claim 1, wherein:

the management function is corrected, such that the predicted concentration calculated using the management function is corrected to an actual measured concentration of the first agent in the groundwater, by:

replacing the initial concentration with a concentration of the first agent in the groundwater after a predetermined time has elapsed, and

changing the injection concentration.

11. The contaminated soil purification method of claim 5, wherein:

the management function is corrected, such that the predicted temperature calculated using the management function is corrected to an actual measured temperature of the groundwater in the second well, by:

replacing the initial temperature with a temperature of the groundwater in the second well after a predetermined time has elapsed, and

changing the injection temperature.

12. The contaminated soil purification method of claim 6, wherein:

the management function is corrected, such that the predicted concentration and the

predicted temperature calculated using the management function are corrected to an actual measured concentration of the first agent in the groundwater and an actual measured temperature of the groundwater in the second well, by:

replacing the initial concentration and the initial temperature with a concentration of the first agent in the groundwater and a temperature of the groundwater in the second well after a predetermined time has elapsed, and

changing the injection concentration or the injection temperature.