improved separation performance and a method of manufacturing an adsorption apparatus by which the adsorption apparatus can be manufactured.

Solution to Problem

[0015] The object is achieved by the present invention described in (1) to (11) below.

(1) An adsorption apparatus including:

a column main body that is tubular and includes an adsorbent filling space therein;

a first port provided at one end of the column main body and having a first flow path through which liquid flows;

a second port provided at the other end of the column main body and having a second flow path through which liquid flows; and

an adsorbent that is charged in the adsorbent filling space,

wherein

the adsorbent contains a powder formed from aggregates of fine particles having a non-constant particle size, and

$0.72 \leq A1/A3 \leq 1.38$ is satisfied, where a modal particle size in a particle size distribution of the powder present in a first region, which is one end of the adsorbent filling space, is A1 [μm], and a modal particle size in a particle size distribution of the powder present in a third region, which is the other end of the adsorbent filling space, is A3 [μm].

[0016] As described above, A1/A3, as a parameter representing the uniformity of the modal particle sizes A1 and A3 of the adsorbent present in the first region and the third region, which are both ends of the adsorbent filling space, satisfies the relationship $0.72 \leq A1/A3 \leq 1.38$. In other words, a lower limit value of A1/A3 is 0.72. An upper limit value of A1/A3 is 1.38. Therefore, it can be said that the adsorbent is charged in the adsorbent filling space with a substantially uniform particle size distribution, and the column performance of purifying and isolating substances to be adsorbed can be reliably imparted to an adsorption apparatus that includes the adsorbent. Furthermore, excellent durability can be imparted to the adsorbent included in the column.

[0017] (2) The adsorption apparatus according to (1), wherein the powder adsorbs a substance to be adsorbed when a sample solution containing the substance is supplied to the adsorbent filling space via the first flow path of the first-port in a state in which the first-port is located vertically above the second-port.

The adsorption apparatus of the present invention is suitably applied to an adsorption apparatus having such a configuration.

[0018] (3) The adsorption apparatus according to (2), wherein $0.72 \leq A1/A2 \leq 1.38$ is satisfied, where a modal particle size in a particle size distribution of the powder in a

second region located at a midpoint between the one end and the other end is A2 [μm].

[0019] As a result, it can be said that the adsorbent is charged in the adsorbent filling space with a more uniform particle size distribution.

[0020] (4) The adsorption apparatus according to (3), wherein $0.80 \leq B1/B2 \leq 1.15$ is satisfied, where a frequency of the modal particle size in the particle size distribution of the powder in the first region is B1 (%), and a frequency of the modal particle size in the particle size distribution of the powder in the second region is B2 (%).

[0021] As a result, it can be said that the adsorbent is charged in the adsorbent filling space with a more uniform particle size distribution.

[0022] (5) A method of manufacturing an adsorption apparatus, including:

a first step of preparing a column including: a column main body that is tubular and has an adsorbent filling space therein; a first port provided at one end of the column main body and having a first flow path through which liquid flows; and a second port provided at the other end of the column main body and having a second flow path through which liquid flows;

a second step of charging a composition including an adsorbent containing a powder formed from aggregates of fine particles having a non-constant particle size and a first liquid into the adsorbent filling space of the column; and

a third step of supplying a second liquid to the adsorbent filling space via the first flow path of the first port in a state in which the first port side of the column is located vertically below.

[0023] According to the method of manufacturing an adsorption apparatus of the present invention, the adsorbent can be charged, with a substantially uniform particle size distribution, in the adsorbent filling space included in the column main body.

[0024] (6) The method of manufacturing an adsorption apparatus according to (5), further including, prior to the second step,

a step of preparing an extension column including: a column passage section that is tubular and has an adsorbent passage space therein; a cover body provided at one end of the column passage section and having a third flow path through which liquid flows; and a connection section provided at the other end of the column passage section and connectable to the one end side of the column main body; and

a step of connecting, via the connection section, the other end of the column passage section to the one end of the column main body in a state in which the first port is disengaged.

[0025] As a result, the adsorbent can be charged, with a substantially uniform particle size distribution, in the adsorbent filling space included in the column main body.

[0026] (7) The method of manufacturing an adsorption apparatus according to (5) or (6), wherein the adsorption apparatus obtained through the third step satisfies $0.72 \leq A1/A3 \leq 1.38$, where a modal particle size in a particle size distribution of the powder

disposed such that the extension column 200 is located vertically below and [S4B-2] in which the filling solution 66 (second liquid) is supplied to the column 2 (column main body 21) side from the extension column 200 side in the column connection body 250.

[0081] These steps [S4B-1] and [S4B-2] constituting the present step [S4B] will be described sequentially.

[0082] [S4B-1: Step of disposing column connection body 250 with extension column 200 side being located vertically below]

In this step, the column connection body 250 in which the slurry 30 is charged in the adsorbent passage space 220 included in the column passage section 221 of the extension column 200 is disposed such that the extension column 200 side is located vertically below.

[0083] Specifically, the cap 228 is attached, by screwing, to the inflow side end (upper end) of the column passage section 221 of the extension column 200, in the column connection body 250 in which the slurry 30 is charged in the adsorbent passage space 220 included in the column passage section 221 of the extension column 200.

[0084] Next, as shown in FIG. 5, the column connection body 250 in which the column main body 21 of the column 2 and the column passage section 221 of the extension column 200 are connected to each other is disposed such that the column main body 21 of the column 2 is located vertically above, and the column passage section 221 of the extension column 200 is located vertically below. That is, in the column connection body 250 in which the column 2 and the extension column 200 are connected to each other, the column connection body 250 is disposed such that the inflow side end of the column connection body 250 is located vertically below, and the outflow side end of the column connection body 250 is located vertically above.

[0085] Note that, when the column connection body 250 is disposed in such a manner, the filling solution 66 (second liquid) may not be supplied to the adsorbent passage space 220 of the column passage section 221 via the inlet pipe 224 of the cap 228, but it is preferable to supply the filling solution 66 to the adsorbent passage space 220 in advance. As a result, as illustrated in FIGS. 4 through 5, when the column connection body 250 is inverted such that the extension column 200 is changed to be located vertically below from the state in which it is located vertically above, the adsorbent 3 charged in the adsorbent passage space 220 can be securely suppressed or prevented from unintentionally flowing down toward the inflow side end side of the column passage section 221, that is, toward the cap 228 side.

[0086] In a case where the filling solution 66 is supplied in advance to the adsorbent passage space 220, the filling solution 66 is started to be supplied to the adsorbent passage space 220 of the column passage section 221 via the inlet pipe 224 of the cap 228, in a state in which the column connection body 250 is disposed such that the

more uniform particle size distribution, and the effect can be more significantly exhibited.

[0102] Furthermore, when a frequency of the modal particle size A2 in the particle size distribution of the adsorbent 3 present in the second region a2 is B2 (%), B1/B2 preferably satisfies $0.80 \leq B1/B2 \leq 1.15$, more preferably satisfies $0.85 \leq B1/B2 \leq 1.10$, further preferably satisfies $0.90 \leq B1/B2 \leq 1.05$, and even more preferably satisfies $0.95 \leq B1/B2 \leq 1.02$, in addition to the relationship between the frequencies B1 and B3 of the modal particle sizes A1 and A3 of the adsorbents 3 present in the first region a1 and the third region a3. In other words, a lower limit value of the B1/B2 is preferably 0.80, more preferably 0.85, further preferably 0.90, and even more preferably 0.95. An upper limit value of the B1/B2 is preferably 1.15, more preferably 1.10, further preferably 1.05, and even more preferably 1.02.

[0103] In addition, as for the relationship between the frequencies B1 and B2 of the modal particle sizes A1 and A2 of the adsorbents 3 present in the first region a1 and the second region a2, |B1-B2| as another parameter representing the uniformity of the adsorbents 3 present in the first region a1 and the second region a2 preferably satisfies the relationship of $|B1-B2| \leq 3.0\%$, and more preferably satisfies the relationship $0.5\% \leq |B1-B2| \leq 3.0\%$, in addition to the above relationship of the B1/B2. In other words, a lower limit value of the |B1-B3| is more preferably 0.5%. Moreover, an upper limit value of the |B1-B3| is preferably 3.0%.

[0104] From the fact that the frequencies B1 and B2 of the modal particle sizes A1 and A2 of the adsorbents 3 present in the first region a1 and the second region a2 satisfy the relationship described above, it can be said that the adsorbent 3 is charged in the adsorbent filling space 20 with a more uniform particle size distribution, and the effect can be more significantly exhibited.

[0105] When median particle sizes of the adsorbents 3 present in the first regions a1, the second regions a2, and the third regions a3 are C1, C2, and C3, respectively, C1/C3 preferably satisfies a formula $0.7 \leq C1/C3 \leq 1.3$. The value more preferably satisfies a formula $0.8 \leq C1/C3 \leq 1.2$, and further preferably satisfies a formula $0.9 \leq C1/C3 \leq 1.1$.

[0106] Furthermore, when the median particle sizes of the adsorbents 3 present in the first regions a1, the second regions a2, and the third regions a3 are C1, C2, and C3, respectively, C1, C2, and C3 preferably satisfy $0.9 \leq C1/C3 \leq 1.1$ and $0.9 \leq C1/C2 \leq 1.1$, and more preferably satisfy $0.95 \leq C1/C3 \leq 1.05$ and $0.95 \leq C1/C2 \leq 1.05$.

[0107] Also, when average particle sizes of the adsorbents 3 present in the first regions a1, the second regions a2, and the third regions a3 are D1, D2, and D3, respectively, D1, D2, and D3 preferably satisfy $0.9 \leq D1/D3 \leq 1.1$ and $0.9 \leq D1/D2 \leq 1.1$, and more preferably satisfy $0.95 \leq D1/D3 \leq 1.05$ and $0.95 \leq D1/D2 \leq 1.05$.

Claims

[Claim 1]
An adsorption apparatus comprising:
a column main body that is tubular and comprises an adsorbent filling space therein;
a first port provided at one end of the column main body and having a first flow path through which liquid flows;
a second port provided at the other end of the column main body and having a second flow path through which liquid flows; and
an adsorbent that is charged in the adsorbent filling space,
wherein
the adsorbent comprises a powder formed from aggregates of fine particles having a non-constant particle size, and
$0.72 \leq A1/A3 \leq 1.38$ is satisfied, where a modal particle size in a particle size distribution of the powder present in a first region, which is one end of the adsorbent filling space, is A1 [μm], and a modal particle size in a particle size distribution of the powder present in a third region, which is the other end of the adsorbent filling space, is A3 [μm].

[Claim 2]
The adsorption apparatus according to claim 1, wherein the powder adsorbs a substance to be adsorbed when a sample solution containing the substance is supplied to the adsorbent filling space via the first flow path of the first port in a state in which the first port is located vertically above the second port.

[Claim 3]
The adsorption apparatus according to claim 2, wherein $0.72 \leq A1/A2 \leq 1.38$ is satisfied, where a modal particle size in a particle size distribution of the powder in a second region located at a midpoint between the one end and the other end is A2 [μm].

[Claim 4]
The adsorption apparatus according to claim 3, wherein $0.80 \leq B1/B2 \leq 1.15$ is satisfied, where a frequency of the modal particle size in the particle size distribution of the powder in the first region is B1 (%), and a frequency of the modal particle size in the particle size distribution of the powder in the second region is B2 (%).

[Claim 5]
A method of manufacturing an adsorption apparatus, comprising:
a first step of preparing a column comprising: a column main body that is tubular and has an adsorbent filling space therein; a first port provided at one end of the column main body and having a first flow path through which liquid flows; and a second port provided at the other end of the column main body and having a second flow path through which liquid flows;
a second step of charging a composition comprising an adsorbent containing a powder formed from aggregates of fine particles having a non-constant particle size and a first liquid into the adsorbent filling space of the column; and
a third step of supplying a second liquid to the adsorbent filling space via the first flow path of the first port in a state in which the first port side of the column is located vertically below.

[Claim 6]
The method of manufacturing an adsorption apparatus according to claim 5, further comprising, prior to the second step:

a step of preparing an extension column comprising: a column passage section that is tubular and has an adsorbent passage space therein; a cover body provided at one end of the column passage section and having a third flow path through which liquid flows; and a connection section provided at the other end of the column passage section and connectable to the one end side of the column main body; and

a step of connecting, via the connection section, the other end of the column passage section to the one end of the column main body in a state in which the first port is disengaged.

[Claim 7]

The method of manufacturing an adsorption apparatus according to claim 5 or 6, wherein the adsorption apparatus obtained through the third step satisfies $0.72 \leq A1/A3 \leq 1.38$, where a modal particle size in a particle size distribution of the powder present in a region at one end of the adsorbent filling space is A1 [μm], and a modal particle size in a particle size distribution of the powder present in a region at the other end of the adsorbent filling space is A3 [μm].