the cost of treatment for single use hi-dose machines. It is accordingly desirable to reuse the materials of the sorbent column, especially the sorbent layers including zirconium phosphate and oxide. U.S. Patent No. 9,707,329 ("the '329 Patent") describes routines for regenerating zirconium from a used sorbent cartridge. Fig. 2 from the '329 Patent shows that in the illustrated example, three different filtering and washing steps are required. The multiple washing and filtering steps are costly and labor intensive, and at some point, may cost more than the money saved in reusing the zirconium.

[0007] A need exists accordingly to provide an improved way to regenerate used sorbent column zirconium materials.

SUMMARY

[0008] The examples described herein disclose systems and methods to improve any treatment that uses sorbent materials to clean an effluent fluid. In particular, the systems and methods refurbish used sorbent materials, reducing the overall cost of the sorbent treatment. The treatment systems generally involve hemodialysis ("HD") systems. The HD systems of the present disclosure in various examples include a dialysis fluid circuit separated from a blood circuit by a dialyzer. The blood circuit includes one or more blood pump, e.g., a blood pump pumping along the arterial line. The blood circuit includes one or more air trap, e.g., an airtrap located in the venous line. The arterial line connects to a blood inlet of the dialyzer, while the venous line connects to a blood outlet of the dialyzer. Other blood circuit components are described herein.

[0009] The dialysis fluid circuit in an example includes a fresh dialysis fluid pump pumping fresh and regenerated dialysis fluid to a dialysis fluid inlet of the dialyzer and a used dialysis fluid pump pumping used dialysis fluid from a dialysis fluid outlet of the dialyzer to and through a sorbent cartridge, which removes the waste products listed above and acquired from the patient's blood via transfer through semi-permeable membranes located within the dialyzer. An infusate pump pumps infusate from an infusate source into the dialysis fluid circuit at a point downstream of the sorbent cartridge. The infusate replenishes the cleansed dialysis fluid, restoring the dialysis fluid into a form that may be pumped again to the dialyzer to treat the patient's blood.

[0010] The dialysis fluid circuit also includes a drain line, which enables used dialysis fluid at the end of treatment to be pumped to drain. Various valves are located in the blood and dialysis fluid circuits to control fluid flow as desired during treatment. All blood and dialysis fluid pumps

and valves are operated under control of a control unit, which also accepts inputs from various sensors operating with the blood and dialysis fluid circuits, such as pressure sensors, conductivity sensors, air detection sensors, blood detection sensors, ammonia and other chemical sensors.

[0011] Structure and methodology are provided for removing a controlled amount of ultrafiltration ("UF") from the patient, such as a separate UF pump or one or more weigh scales outputting to the control unit. Volumetric UF control, such as balance chambers in the dialysis fluid circuit, may be provided alternatively. Any of the blood and dialysis fluid pumps and valves may be operated electrometrically, e.g., via peristaltic pumps and electrically actuated solenoid valves, or alternatively pneumatically, e.g., via volumetric pumps and pneumatic valves.

[0012] At the end of treatment using the above-described HD system, the sorbent cartridge is removed from the dialysis fluid circuit and at least some of the layers of material within the sorbent column are cleaned and regenerated according to the examples described below. It is contemplated to regenerate the sorbent materials in at least two different manners. In a first manner, the patient or caregiver collects the used sorbent cartridges. The collected used cartridges are either picked up or delivered periodically to a facility where they are cleaned and regenerated in a batch manner along with used sorbent materials from other patients. Here, the patient or caregiver receives a delivery of fresh sorbent cartridges periodically. In a second manner, at least a portion of the used sorbent cartridges are cleaned and regenerated onsite, either in a clinic or at home. In one example, any zirconium containing layers are cleaned and regenerated and then repacked into the sorbent column along with new single use layers. Single use layers in various examples include any one or more of a mechanical purification layer, a urease layer, an anion exchange layer and/or an activated carbon layer.

[0013] As discussed in detail below, the sorbent conditioning of the present disclosure may also be employed to refurbish used sorbent materials from peritoneal dialysis ("PD") systems and treatments.

[0014] With the above in mind, two primary examples are contemplated for cleaning and regenerating at least a portion of the sorbent layers, such as the zirconium containing layers.

Batch Refurbishing

[0015] In one primary example, sorbent material refurbishing is performed in a batch operation in which used sorbent materials from multiple sorbent cartridges are combined and cleaned together. The sorbent refurbishing process in one example provides an adequate ammonium removal capacity of zirconium phosphate containing greater than 90% sodium or hydrogen exchange sites. The sorbent refurbishing in various implementations involves the use of a disinfecting agent in combination with an acid, base or sodium salt treatment. The sorbent refurbishing is applicable to sorbent cartridges having different zirconium containing compartments provided in a serial (e.g., layered) or parallel (e.g., used dialysis fluid flows through one or the other compartment) configuration.

[0016] It is contemplated to provide the batch sorbent refurbishing process in any one of several different implementations of the first primary example. In each case, used zirconium containing sorbent materials from multiple sorbent cartridges for a single or multiple patients are collected at a refurbishing facility. The total batch to be refurbished in one procedure may be in the range of 10 lbs. to 10000 lbs. In a first implementation, (i) non-disinfected zirconium phosphate ("ZP") is refurbished using an acid solution, (ii) the regenerated ZP is disinfected using a disinfecting agent, (iii) the disinfected and acid regenerated ZP is washed and filtered, (iv) the washed ZP is titrated to a desired pH, for example between and including 5.5 to 8.5, (v) the titrated ZP is washed and filtered to a conductivity below 50 μS/cm, (vi) the washed ZP is dried, e.g., in a vacuum oven, and (vii) the dried ZP is sieved using one or more sieves for one or more sorbent uses. The ZP is now ready to be reused.

[0017] In a second implementation, the titration and second washing procedures above are removed, such that non-disinfected zirconium phosphate ("ZP") is (i) regenerated using an acid solution, (ii) disinfected using a disinfecting agent, (iii) washed and filtered, (iv) dried, e.g., in a vacuum oven, and (v) sieved using one or more sieves for one or more sorbent uses. The ZP is now ready to be reused.

[0018] In a third implementation, the acid solution of the first implementation is replaced with a sodium based alkaline solution or a sodium salt solution, such that (i) non-disinfected zirconium phosphate ("ZP") is regenerated using a sodium based alkaline solution or a sodium salt solution, (ii) the regenerated ZP is disinfected using a disinfecting agent, (iii) the disinfected and sodium regenerated ZP is washed and filtered, (iv) the washed ZP is titrated to a desired pH, for

example between and including 5.5 to 8.5, (v) the titrated ZP is washed and filtered to a conductivity below 50 μS/cm, (vi) the washed ZP is dried, e.g., in a vacuum oven, and (vii) the dried ZP is sieved using one or more sieves for one or more sorbent uses. The ZP is now ready to be reused.

[0019] In a fourth implementation, the acid solution of the second implementation is replaced with a sodium based alkaline solution or a sodium salt solution, such that (i) non-disinfected zirconium phosphate ("ZP") is regenerated using a sodium based alkaline solution or a sodium salt solution, (ii) the regenerated ZP is disinfected using a disinfecting agent, (iii) the disinfected and sodium regenerated ZP is washed and filtered, (iv) the washed ZP is dried, e.g., in a vacuum oven, and (v) the dried ZP is sieved using one or more sieves for one or more sorbent uses. The ZP is now ready to be reused.

[0020] In a fifth implementation, the regenerating and disinfecting procedures of the third implementation are reversed, such that (i) non-regenerated ZP is disinfected using a disinfecting agent, (ii) disinfected zirconium phosphate ("ZP") is regenerated using a sodium based alkaline solution or a sodium salt solution, (iii) the disinfected and sodium regenerated ZP is washed and filtered, (iv) the washed ZP is titrated to a desired pH, for example between and including 5.5 to 8.5, (v) the titrated ZP is washed and filtered to a conductivity below 50 μS/cm, (vi) the washed ZP is dried, e.g., in a vacuum oven, and (vii) the dried ZP is sieved using one or more sieves for one or more sorbent uses. The ZP is now ready to be reused.

[0021] In a sixth implementation, the regenerating and disinfecting procedures of the fourth example are revered, such that (i) non-regenerated ZP is disinfected using a disinfecting agent, (ii) disinfected zirconium phosphate ("ZP") is regenerated using a sodium based alkaline solution or a sodium salt solution, (iii) the disinfected and sodium regenerated ZP is washed and filtered, (iv) the washed ZP is dried, e.g., in a vacuum oven, and (v) the dried ZP is sieved using one or more sieves for one or more sorbent uses. The ZP is now ready to be reused.

[0022] In any of the above implementations, the disinfecting agent may contain different types of chemicals. In one example, the chemical is sodium based, such as NaOCl in isopropyl alcohol ("IPA"). In another example, the chemical is a hydrogen based chemical, such as HOCl in IPA. A third example includes IPA as the primary disinfecting agent. Also, any of the above examples for preparing ZP for reuse is applicable to other zirconium containing materials, such

as zirconium oxide ("ZO") and to different types of ZP, such as H^+ZP and Na^+ZP. Additionally, the acid soltiuon may be HCl, H_2SO_4, H_3PO_4, HNO_3 or acetic acid, and the sodium based alkaline solution or a sodium salt solution may be NaOH, $NaHCO_3$, Na_2CO_3 or NaCl.

[0023] The ZP made ready for reuse via any of the implementations above is placed within the column of a sorbent cartridge, e.g., in serial or parallel fashion with other zirconium containing materials, and with reused and/or new non-zirconium layers, such as mechanical filtration, urease and activated carbon layers. The layers form a refurbished sorbent cartridge that is deliverable to the patient along with other refurbished cartridges to be used over multiple treatments.

Onsite Refurbishing

[0024] In a second primary example, sorbent material refurbishing is performed in an onsite operation in which at least the zirconium containing materials (e.g., ZO, H^+ZP and Na^+ZP) are conditioned for reuse. As with the previous primary example, the sorbent refurbishing process of the second primary example may provide an adequate ammonium removal capacity of zirconium phosphate containing greater than 90% sodium or hydrogen exchange sites. The sorbent refurbishing cleaning in various implementations again involves the use of a disinfecting agent in combination with an acid, base or sodium salt treatment. The sorbent refurbishing is applicable to sorbent cartridges having different zirconium containing compartments provided in a serial (e.g., layered) or in parallel (e.g., used dialysis fluid flows through one or the other compartment).

[0025] A major difference between the first and second primary examples is that in the batch process, the sorbent materials are removed from their layering casing, so that the materials from multiple sorbent cartridges may be mixed together and refurbished at once. In the onsite example, on the other hand, the sorbent materials are left to reside within their casing, for ease of handling and so that the patient or caregiver does not have to handle the sorbent materials directly.

[0026] Another difference between the first and second primary examples may be that the same conditioning implementations are used for both H^+ZP and Na^+ZP in the first primary example, while a first conditioning implementation is used for H^+ZP versus a second conditoning implementation used for Na^+ZP in the second primary example. It should be appreciated however that the reverse may be true, namely, different conditioning implementations

may be developed for H^+ZP versus Na^+ZP for the batch example, while the same conditioning implementation may be developed for H^+ZP and Na^+ZP for the onsite example.

[0027] It is contemplated to provide the onsite sorbent refurbishing cleaning process in any one of several different implementations. In each case, used zirconium containing sorbent layer casings are removed from the patient's sorbent cartridge along with the non-zirconium layer casings (e.g., mechanical filtration casing, urease casing and activated carbon casing(s)). The non-zirconium layer casings may also be conditioned for reuse or discarded.

[0028] In a first implementation, which may be specific to conditioning H^+ZP, (i) non-disinfected H^+ZP is regenerated within its casing in a reverse flow direction, such that the casing inlet during treatment becomes the casing outlet during regeneration and vice versa, using an acid solution through the casing at a flow rate of for example 0.1ml/min to 5ml/min and at a temperature from about 20°C to about 80°C, which may be performed until the pH of the eluent (acid used to contact H^+ZP) equals or approaches the pH of the incoming acid solution, (ii) water is rinsed through the regenerated H^+ZP within its casing (e.g., in the reverse flow direction) until conductivity of the effluent (water used to wash regenerated H^+ZP) reaches a conductivity of 100 µS/cm or less, (iii) the regenerated and rinsed H^+ZP is disinfected via a disinfecting agent (which may contain a hydrogen based chemical such as HOCl in IPA**)** flowed, e.g., pumped, through the H^+ZP casing (e.g., in the reverse flow direction); and (iv) flow is reversed and water is rinsed through the regenerated and disinfected H^+ZP though its casing in the normal treatment flow direction until conductivity of the eluent (water used to wash regenerated and disinfected H^+ZP) reaches a conductivity of 100 µS/cm or less. The H^+ZP casing, e.g., after drying, is ready to be reintroduced into the sorbent cartridge and reused.

[0029] In a second implementation, which may be specific to conditioning Na^+ZP, (i) non-disinfected Na^+ZP is regenerated within its casing in a reverse flow direction, such that the casing inlet during treatment becomes the casing outlet during regeneration and vice versa, and a sodium based alkaline solution or a sodium salt solution is flowed, e.g., pumped, through the casing at a flow rate of for example 0.1ml/min to 5ml/min and at a temperature from about 20°C to about 80°C, which may be performed until the conductivity of the conductivity of the eluent (sodium solution used to contact Na^+ZP) equals or approaches the conductivity of the incoming sodium solution, (ii) water is rinsed through the regenerated Na^+ZP within its casing (e.g., in the reverse

flow direction,) for a determined time (conductivity already controlled in (i)), (iii) the regenerated and rinsed Na^+ZP is disinfected via a disinfecting agent (may contain a sodium based chemical such as NaOCl in IPA**)** flowed, e.g., pumped, through the Na^+ZP casing (e.g., in the reverse flow direction); and (iv) flow is reversed and water is rinsed through the regenerated and disinfected Na^+ZP casing in the normal treatment flow direction until conductivity of the eluent (water used to wash regenerated and disinfected Na^+ZP) reaches a conductivity of 100 µS/cm or less. The Na^+ZP casing, e.g., after drying, is ready to be reintroduced into the sorbent cartridge and reused.

[0030] In a third implementation, which may also be specific to conditioning Na^+ZP, the regeneration and disinfection procedures of the second implementation are reversed, such that (i) used and non-regenerated Na^+ZP is disinfected within its casing in a normal treatment or reverse flow direction using a disinfecting agent that may contain a sodium based chemical such as NaOCl in IPA, (ii) water is rinsed through the disinfected Na^+ZP within its casing (in normal treatment or reverse flow direction) to remove residual chemicals until the conductivity of the eluent (water used to wash disinfected Na^+ZP) reaches a conductivity of 100 µS/cm or less; (iii) disinfected Na^+ZP is regenerated within its casing in the reverse flow direction, such that the casing inlet during treatment becomes the casing outlet during regeneration and vice versa, and a sodium based alkaline solution or a sodium salt solution is flowed, e.g., pumped, through the casing at a flow rate of for example 0.1ml/min to 5ml/min and at a temperature from about 20°C to about 80°C, which may be performed until the conductivity of the eluent (sodium solution used to contact Na^+ZP) equals or almost equals the conductivity of the incoming sodium solution; and (iv) flow is reversed and water is rinsed through the disinfected and regenerated Na^+ZP though its casing in the normal treatment flow direction, e.g., for a determined amount of time (conductivity already controlled in (ii) and (iii)). The Na^+ZP casing, e.g., after drying, is now ready to be reintroduced into the sorbent cartridge and reused.

[0031] Once any or all of the H^+ZP and Na^+ZP casings are conditioned for reuse, the patient or caregiver inserts the reusable casings into the sorbent cartridge along with any additional casings, e.g., mechanical filtration casing, urease casing and/or activated carbon casing(s), which may themselves have been conditioned for reuse or opened from a sterile package as a new casing. The patient or caregiver inserts the casings in a proper order and orientation, which may be aided by markings provided on the outside of sorbent cartridge. Alternatively or additionally, the

cartridge and casings may be somewhat conical in shape so that the casings only fit snugly within the cartridge when stacked in the proper order and orientation.

[0032] In an example, the sorbent cartridge is closed at one end, e.g., the outlet end, and openable at the other end, e.g., the inlet end, such that the user (e.g., patient, caregiver, clinician or technician) in one example only has to (i) open one side of the cartridge to remove all inner sorbent casings, (ii) condition the casings to be reused, (iii) replace the casings to be discarded, (iv) rinse the cartridge itself, (v) reinsert the refurbished and new casings into the rinsed cartridge, and (vi) close the opened end of the cartridge. In various examples, the inlet lid or cap may thread onto the remainder of the cartridge housing or be held removeably fixed to the housing via releasable clips, such as spring clips. In either case, it is contemplated that the action of applying the lid or cap to the remainder of the cartridge in turn compresses the sorbent casings together, compressing seals (e.g., o-ring seals) between the casings, such that patient effluent cannot leak between the casings and the inner cartridge. The seals may be captured and carried by the casings for ease of handling when the casings are removed from the sorbent cartridge.

[0033] The onsite operation may be performed in a dialysis clinic, at a hospital, or at a patient's home, for example. At a clinic, the sorbent casing removal and replacement may be performed by a clinician or technician. At a hospital, the sorbent casing removal and replacement may be performed by a nurse or technician. At home, the sorbent casing removal and replacement may be performed by the patient or a caregiver for the patient.

[0034] It is further contemplated to provide at the clinic, hospital, patient's home or offsite one or more sorbent conditioning or refurbishing device. The device may be configured to condition or refurbish (i) one sorbent casing at a time, (ii) multiple sorbent casings of a same type at the same time, (iii) multiple sorbent casings of different types at the same time, (iv) multiple sorbent casings of a same type sequentially, or (v) multiple sorbent casings of different types sequentially. The sorbent conditioning or refurbishing device accepts the one or more sorbent casing in a sealed manner, conditions or refurbishes the one or more sorbent casing according to any of the implementations discussed above for the onsite primary example, and informs the user when the casing is ready to be removed from the conditioning or refurbishing device and reused.

[0035] In light of the disclosure herein and without limiting the disclosure in any way, in a first example of the present disclosure, which may be combined with any other example listed herein unless specified otherwise, a medical fluid delivery method includes providing a sorbent cartridge including H^+ZP within a casing for a treatment; and after the treatment, refurbishing the H^+ZP while maintained within the casing via (i) regenerating the non-disinfected H^+ZP by flowing an acid solution through the casing, (ii) rinsing the regenerated H^+ZP while maintained within the casing, (iii) disinfecting the regenerated and rinsed H^+ZP by flowing a disinfecting agent through the casing, and (iv) rinsing the regenerated and disinfected H^+ZP while maintained within the casing.

[0036] In a second example of the present disclosure, which may be combined with any other example listed herein unless specified otherwise, at least one of the rinsing procedures includes rinsing the H^+ZP with water through the casing until a desired conductivity is reached.

[0037] In a third example of the present disclosure, which may be combined with any other example listed herein unless specified otherwise, the first rinsing procedure includes rinsing the H^+ZP with water through the casing in a reverse-to-treatment flow direction and the second rinsing procedure includes rinsing the H^+ZP with water through the casing in a normal treatment flow direction.

[0038] In a example aspect of the present disclosure, which may be combined with any other example listed herein unless specified otherwise, disinfecting the rinsed and regenerated H^+ZP includes flowing the disinfecting agent through the casing in a reverse-to- treatment flow direction.

[0039] In a fifth example of the present disclosure, which may be combined with any other example listed herein unless specified otherwise, regenerating the non-disinfected H^+ZP includes flowing the acid solution through the casing in a reverse-to-treatment flow direction.

[0040] In a sixth example of the present disclosure, which may be combined with any other example listed herein unless specified otherwise, regenerating the non-disinfected H^+ZP includes at least one of flowing the acid solution through the casing (i) at a flowrate of 0.1ml/min to 5ml/min, (ii) at a temperature from about 20°C to about 80°C, or (iii) until eluent acid used to contact the H^+ZP has a pH that equals or substantially equals a pH of incoming acid solution.

[0041] In a seventh example of the present disclosure, which may be combined with any other example listed herein unless specified otherwise, at least one of (a) the acid solution is HCl,

H_2SO_4, H_3PO_4, HNO_3 or acetic acid or (b) the disinfecting agent (i) is a hydrogen based chemical, such as including HOCl or (ii) includes isopropyl alcohol ("IPA").

[0042] In an eighth example of the present disclosure, which may be combined with any other example listed herein unless specified otherwise, the casing including the refurbished H^+ZP is replaced within the sorbent cartridge with at least one new and different type of casing.

[0043] In a ninth example of the present disclosure, which may be combined with any other example listed herein unless specified otherwise, a medical fluid delivery method includes providing a sorbent cartridge including Na^+ZP within a casing for a treatment; and after the treatment, refurbishing the Na^+ZP while maintained within the casing via (i) regenerating the non-disinfected NA^+ZP using by flowing a sodium based alkaline solution or a sodium salt solution through the casing, (ii) rinsing the regenerated NA^+ZP while maintained within the casing, (iii) disinfecting the regenerated and rinsed NA^+ZP by flowing a disinfecting agent through the casing, and (iv) rinsing the regenerated and disinfected NA^+ZP while maintained within the casing.

[0044] In a tenth example of the present disclosure, which may be combined with the ninth example and any other example listed herein unless specified otherwise, at least one of the rinsing procedures includes rinsing the NA^+ZP with water through the casing until a desired conductivity is reached.

[0045] In an eleventh example of the present disclosure, which may be combined with the ninth example and any other example listed herein unless specified otherwise, the first rinsing procedure includes rinsing the NA^+ZP with water through the casing in a reverse-to-treatment flow direction and the second rinsing procedure includes rinsing the NA^+ZP with water through the casing in a normal treatment flow direction.

[0046] In a twelfth example of the present disclosure, which may be combined with the ninth example and any other example listed herein unless specified otherwise, disinfecting the rinsed and regenerated NA^+ZP includes flowing the disinfecting agent through the casing in a reverse-to- treatment flow direction.

[0047] In a thirteenth example of the present disclosure, which may be combined with the ninth example and any other example listed herein unless specified otherwise, regenerating the non-disinfected NA^+ZP includes flowing the sodium based alkaline solution or the sodium salt solution through the casing in a reverse-to-treatment flow direction.

[0048] In a fourteenth example of the present disclosure, which may be combined with the ninth example and any other example listed herein unless specified otherwise, regenerating the non-disinfected NA^+ZP includes at least one of flowing the sodium based alkaline solution or the sodium salt solution through the casing (i) at a flowrate of 0.1ml/min to 5ml/min, (ii) at a temperature from about 20°C to about 80°C, or (iii) until eluent sodium solution used to contact the NA^+ZP has a conductivity that equals or substantially equals a conductivity of incoming sodium solution.

[0049] In a fifteenth example of the present disclosure, which may be combined with the ninth example and any other example listed herein unless specified otherwise, the disinfecting agent (i) is a sodium based chemical, such as including NaOCl or (ii) includes isopropyl alcohol ("IPA").

[0050] In a sixteenth example of the present disclosure, which may be combined with the ninth example and any other example listed herein unless specified otherwise, the casing including the refurbished NA^+ZP is replaced within the sorbent cartridge with at least one new and different type of casing.

[0051] In a seventeenth example of the present disclosure, which may be combined with any other example listed herein unless specified otherwise, a medical fluid delivery method includes: providing a sorbent cartridge including Na^+ZP within a casing for a treatment; and after the treatment, refurbishing the Na^+ZP while maintained within the casing via (i) disinfecting the non-regenerated NA^+ZP by flowing a disinfecting agent through the casing, (ii) rinsing the disinfected NA^+ZP while maintained within the casing, (iii) regenerating the disinfected and rinsed NA^+ZP by flowing a sodium based alkaline solution or a sodium salt solution through the casing, and (iv) rinsing the disinfected and regenerated NA^+ZP while maintained within the casing.

[0052] In an eighteenth example of the present disclosure, which may be combined with the seventeenth example and any other example listed herein unless specified otherwise, at least one of the rinsing procedures includes rinsing the NA^+ZP with water through the casing until a desired conductivity is reached.

[0053] In a nineteenth example of the present disclosure, which may be combined with the seventeenth example and any other example listed herein unless specified otherwise, regenerating the non-disinfected NA^+ZP includes flowing the sodium based alkaline solution or the sodium salt solution through the casing in a reverse-to-treatment flow direction.

[0054] In a twentieth example of the present disclosure, which may be combined with the nineteenth example and any other example listed herein unless specified otherwise, the second rinsing procedure includes rinsing the $NA^{+}ZP$ with water through the casing in a normal treatment flow direction.

[0055] In a twenty-first example of the present disclosure, which may be combined with the seventeenth example and any other example listed herein unless specified otherwise, regenerating the disinfected $NA^{+}ZP$ includes at least one of flowing the sodium based alkaline solution or the sodium salt solution through the casing (i) at a flowrate of 0.1ml/min to 5ml/min, (ii) at a temperature from about 20°C to about 80°C, or (iii) until eluent sodium solution used to contact the $NA^{+}ZP$ has a conductivity that equals or substantially equals a conductivity of incoming sodium solution.

[0056] In a twenty-second example of the present disclosure, which may be combined with the seventeenth example and any other example listed herein unless specified otherwise, the disinfecting agent (i) is a sodium based chemical, such as including NaOCl or (ii) includes isopropyl alcohol ("IPA").

[0057] In a twenty-third example of the present disclosure, which may be combined with the seventeenth example and any other example listed herein unless specified otherwise, the casing including the refurbished $NA^{+}ZP$ is replaced within the sorbent cartridge with at least one new and different type of casing.

[0058] In a twenty-fourth example of the present disclosure, which may be combined with any other example listed herein unless specified otherwise, a sorbent cartridge includes (i) a housing sized and shaped to accept multiple sorbent cartridge casings in a desired order; (ii) a zirconium casing located within the housing; (iii) at least one additional casing located within the housing and selected from a second zirconium casing, a mechanical filter casing, an activated carbon and filter casing, a urease casing, or an anion exchange resin casing; and (iv) wherein each casing includes a seal that seals to another one of the casings or to the housing when the housing is closed for treatment, such that fluid traveling through the housing during treatment is prevented from leaking between the casings and between the housing and the casings.

[0059] In a twenty-fifth example of the present disclosure, which may be combined with the twenty-fourth example and any other example listed herein unless specified otherwise, the housing is

conically sized and shaped to accept multiple sorbent cartridge casings in a desired order and orientation.

[0060] In a twenty-sixth example of the present disclosure, which may be combined with the twenty-fourth example and any other example listed herein unless specified otherwise, each zirconium casing provided includes a refurbished zirconium compound.

[0061] In a twenty-seventh example of the present disclosure, which may be combined with the twenty-fourth example and any other example listed herein unless specified otherwise, the first and second zirconium casings include an $Na^{+}ZP$ casing and an $H^{+}ZP$ casing.

[0062] In a twenty-eighth example of the present disclosure, which may be combined with the twenty-fourth example and any other example listed herein unless specified otherwise, the first and second zirconium casings are located in parallel within the housing.

[0063] In a twenty-ninth example of the present disclosure, which may be combined with the twenty-fourth example and any other example listed herein unless specified otherwise, the first and second zirconium casings are located in series within the housing.

[0064] In a thirtieth example of the present disclosure, which may be combined with the twenty-fourth example and any other example listed herein unless specified otherwise, the housing is closed at its exit end and openable at its inlet end via a removable cap. In a thirty-first example of the present disclosure, which may be combined with any other example listed herein unless specified otherwise, a sorbent refurbishing device includes (i) a cleaning chamber sized and arranged to accept at least one sorbent cartridge casing for refurbishing; (ii) a disinfecting agent source in fluid communication with the cleaning chamber; (iii) a regeneration solution source in fluid communication with the cleaning chamber; (iv) a water source or water connection in fluid communication with the cleaning chamber; (v) at least one pump positioned and arranged to pump at least one of disinfecting agent, regeneration solution, or water to the cleaning chamber; (vi) at least one first valve located between the disinfecting agent source and the cleaning chamber; (vii) at least one second valve located between the regeneration solution source and the cleaning chamber; (viii) at least one third valve located between the water source or water connection and the cleaning chamber; and (ix) a control unit configured to operate the at least one pump, the at least one first valve, the at least one second valve and the at least one third valve to perform a refubishing procedure on the at least one cartridge casing.

[0065] In a thirty-second example of the present disclosure, which may be combined with the thirty-first example and any other example listed herein unless specified otherwise, the cleaning chamber is configured to accept the at least one sorbent cartridge in a particular orientation so that a normal treatment fluid direction and an opposite to normal treatment fluid direction is known.

[0066] In a thirty-third example of the present disclosure, which may be combined with the thirty-first example and any other example listed herein unless specified otherwise, the at least one first valve is positioned and arranged to enable disinfecting agent to be delivered to either of two opposing sides of the cleaning chamber.

[0067] In a thirty-fourth example of the present disclosure, which may be combined with the thirty-first example and any other example listed herein unless specified otherwise, the at least one second valve is positioned and arranged to enable regeneration solution to be delivered to either of two opposing sides of the cleaning chamber.

[0068] In a thirty-fifth example of the present disclosure, which may be combined with the thirty-first example and any other example listed herein unless specified otherwise, the at least one third valve is positioned and arranged to enable water to be delivered to either of two opposing sides of the cleaning chamber.

[0069] In a thirty-sixth example of the present disclosure, which may be combined with the thirty-first example and any other example listed herein unless specified otherwise, the sorbent refurbishing device includes at least one of a conductivity sensor, a temperature sensor, or a pH sensor positioned to sense at least one of the disinfecting agent, the regeneration solution or water, the at least one sensor providing an output to the control unit.

[0070] In a thirty-seventh example of the present disclosure, which may be combined with the thirty-sixth example and any other example listed herein unless specified otherwise, the control unit is configured to use the output to control duration of flow of at least one of the disinfecting agent, the regeneration solution or water.

[0071] In a thirty-eighth example of the present disclosure, which may be combined with the thirty-sixth example and any other example listed herein unless specified otherwise, the sorbent refurbishing device further includes at least one heating coil, the control unit configured to use the output from the temperature sensor to operate the at least one heating coil.

[0072] In a thirty-ninth example of the present disclosure, which may be combined with the thirty-first example and any other example listed herein unless specified otherwise, the sorbent refurbishing device further includes a hot air blower under control of the control unit to dry to the at least one sorbent cartridge casing.

[0073] In a fortieth example of the present disclosure, any of the structure and functionality disclosed in connection with Figs. 1 to 15 may be included or combined with any of the other structure and functionality disclosed in connection with Figs. 1 to 15.

[0073a] In one aspect, the present disclosure refers to a method for refurbishing a sorbent cartridge including H^+ZP within a casing that has been used for treatment comprising:

refurbishing the H^+ZP while maintained within the casing via

regenerating the non-disinfected H^+ZP by flowing an acid solution through the casing,

rinsing the regenerated H^+ZP while maintained within the casing,

disinfecting the regenerated and rinsed H^+ZP by flowing a disinfecting agent through the casing, and

rinsing the regenerated and disinfected H^+ZP while maintained within the casing.

[0073b] In another aspect, the present disclosure refers to a method for refurbishing a sorbent cartridge including Na^+ZP within a casing that has been used for treatment comprising:

refurbishing the Na^+ZP while maintained within the casing via

regenerating the non-disinfected Na^+ZP using by flowing a sodium based alkaline solution or a sodium salt solution through the casing,

rinsing the regenerated Na^+ZP while maintained within the casing,

disinfecting the regenerated and rinsed Na^+ZP by flowing a disinfecting agent through the casing, and

rinsing the regenerated and disinfected Na^+ZP while maintained within the casing.

[0073c] In another aspect, the present disclosure refers to a method for refurbishing a sorbent cartridge including Na^+ZP within a casing that has been used for treatment comprising:

refurbishing the Na^+ZP while maintained within the casing via

disinfecting the non-regenerated Na^+ZP by flowing a disinfecting agent through the casing,

rinsing the disinfected Na^+ZP while maintained within the casing,

regenerating the disinfected and rinsed Na^+ZP by flowing a sodium based alkaline solution or a sodium salt solution through the casing in a reverse-to-treatment flow direction, and

rinsing the disinfected and regenerated Na^+ZP while maintained within the casing in a normal treatment flow direction.

[0073d] In another aspect, the present disclosure refers to a sorbent refurbishing device comprising:

a cleaning chamber sized and arranged to accept at least one sorbent cartridge casing for refurbishing;

a disinfecting agent source in fluid communication with the cleaning chamber;

a regeneration solution source in fluid communication with the cleaning chamber;

a water source or water connection in fluid communication with the cleaning chamber;

at least one pump positioned and arranged to pump at least one of disinfecting agent, regeneration solution, or water to the cleaning chamber;

at least one first valve located between the disinfecting agent source and the cleaning chamber;

at least one second valve located between the regeneration solution source and the cleaning chamber;

at least one third valve located between the water source or water connection and the cleaning chamber; and

a control unit configured to operate the at least one pump, the at least one first valve, the at least one second valve and the at least one third valve to perform a refurbishing procedure on the at least one cartridge casing,

wherein the cleaning chamber is configured to accept the at least one sorbent cartridge in a particular orientation so that a normal treatment fluid direction and an opposite to normal treatment fluid direction is known,

wherein the cleaning chamber provides tapered or conical insert areas to accept the at least one sorbent cartridge casing to prevent leakage and to ensure the at least one sorbent cartridge casing is placed into the cleaning chamber in a desired orientation.

[0074] In light of the present disclosure and the above example, it is therefore an advantage of the present disclosure to provide an improved used sorbent material regeneration system and method.

[0075] It is another advantage of the present disclosure to provide an improved used sorbent material regeneration system and method operable in a batch manner.

[0076] It is a further advantage of the present disclosure to provide an improved used sorbent material regeneration system and method that is operable onsite.

[0077] It is still another advantage of the present disclosure to provide a sorbent cartridge that is readily disassembled and reassembled to remove used sorbent material casings and replace refurbished or new sorbent material casings.

[0078] It is a further advantage of the present disclosure to provide an improved used sorbent material regeneration system and method having a sorbent conditioning or refurbishing device that accepts used sorbent material casings and generates refurbished sorbent material casings.

[0079] The advantages discussed herein may be found in one, or some, and perhaps not all of the examples disclosed herein. Additional features and advantages are described herein, and will be apparent from, the following Detailed Description and the figures.

BRIEF DESCRIPTION OF THE FIGURES

[0080] Fig. 1 is a schematic view of one embodiment of a sorbent hemodialysis ("HD") system that may employ any of the sorbent refurbishing techniques of the pressent disclosure.

[0081] Fig. 2 is a schemaitc view of one embodiment of a sorbent peritoneal dialysis ("PD") system that may employ any of the sorbent refurbishing techniques of the pressent disclosure.

CLAIMS

Claim 1: A method for refurbishing a sorbent cartridge including H^+ZP within a casing that has been used for treatment comprising:

refurbishing the H^+ZP while maintained within the casing via

regenerating the non-disinfected H^+ZP by flowing an acid solution through the casing,

rinsing the regenerated H^+ZP while maintained within the casing,

disinfecting the regenerated and rinsed H^+ZP by flowing a disinfecting agent through the casing, and

rinsing the regenerated and disinfected H^+ZP while maintained within the casing.

Claim 2: The method of Claim 1, wherein at least one of the rinsing procedures includes rinsing the H^+ZP with water through the casing until a desired conductivity is reached.

Claim 3: The method of Claim 1, wherein the first rinsing procedure includes rinsing the H^+ZP with water through the casing in a reverse-to-treatment flow direction and the second rinsing procedure includes rinsing the H^+ZP with water through the casing in a normal treatment flow direction.

Claim 4: The method of Claim 1, wherein disinfecting the rinsed and regenerated H^+ZP includes flowing the disinfecting agent through the casing in a reverse-to-treatment flow direction.

Claim 5: The method of Claim 1, wherein regenerating the non-disinfected H^+ZP includes flowing the acid solution through the casing in a reverse-to-treatment flow direction.

Claim 6: The method of Claim 1, wherein regenerating the non-disinfected H^+ZP includes at least one of flowing the acid solution through the casing (i) at a flowrate of 0.1ml/min

to 5ml/min, (ii) at a temperature from about 20°C to about 80°C, or (iii) until eluent acid used to contact the H^+ZP has a pH that equals or substantially equals a pH of incoming acid solution.

Claim 7: The method of Claim 1, wherein at least one of (a) the acid solution is HCl, H_2SO_4, H_3PO_4, HNO_3 or acetic acid or (b) the disinfecting agent (i) is a hydrogen based chemical, such as including HOCl or (ii) includes isopropyl alcohol ("IPA").

Claim 8: The method of Claim 1, wherein the casing including the refurbished H^+ZP is replaced within the sorbent cartridge with at least one new and different type of casing.

Claim 9: A method for refurbishing a sorbent cartridge including Na^+ZP within a casing that has been used for treatment comprising:

refurbishing the Na^+ZP while maintained within the casing via

regenerating the non-disinfected Na^+ZP using by flowing a sodium based alkaline solution or a sodium salt solution through the casing,

rinsing the regenerated Na^+ZP while maintained within the casing,

disinfecting the regenerated and rinsed Na^+ZP by flowing a disinfecting agent through the casing, and

rinsing the regenerated and disinfected Na^+ZP while maintained within the casing.

Claim 10: The method of Claim 9, wherein at least one of the rinsing procedures includes rinsing the Na^+ZP with water through the casing until a desired conductivity is reached.

Claim 11: The method of Claim 9, wherein the first rinsing procedure includes rinsing the Na^+ZP with water through the casing in a reverse-to-treatment flow direction and the second rinsing procedure includes rinsing the Na^+ZP with water through the casing in a normal treatment flow direction.

Claim 12: The method of Claim 9, wherein disinfecting the rinsed and regenerated Na^+ZP includes flowing the disinfecting agent through the casing in a reverse-to-treatment flow direction.

Claim 13: The method of Claim 9, wherein regenerating the non-disinfected Na^+ZP includes flowing the sodium based alkaline solution or the sodium salt solution through the casing in a reverse-to-treatment flow direction.

Claim 14: The method of Claim 9, wherein regenerating the non-disinfected Na^+ZP includes at least one of flowing the sodium based alkaline solution or the sodium salt solution through the casing (i) at a flowrate of 0.1ml/min to 5ml/min, (ii) at a temperature from about 20°C to about 80°C, or (iii) until eluent sodium solution used to contact the Na^+ZP has a conductivity that equals or substantially equals a conductivity of incoming sodium solution.

Claim 15: The method of Claim 9, wherein the disinfecting agent (i) is a sodium based chemical, such as including NaOCl or (ii) includes isopropyl alcohol ("IPA").

Claim 16: The method of Claim 9, wherein the casing including the refurbished Na^+ZP is replaced within the sorbent cartridge with at least one new and different type of casing.

Claim 17: A method for refurbishing a sorbent cartridge including Na^+ZP within a casing that has been used for treatment comprising:

refurbishing the Na^+ZP while maintained within the casing via

disinfecting the non-regenerated Na^+ZP by flowing a disinfecting agent through the casing,

rinsing the disinfected Na^+ZP while maintained within the casing,

regenerating the disinfected and rinsed Na^+ZP by flowing a sodium based alkaline solution or a sodium salt solution through the casing in a reverse-to-treatment flow direction, and

rinsing the disinfected and regenerated Na^+ZP while maintained within the casing in a normal treatment flow direction.

Claim 18: The method of Claim 17, wherein at least one of the rinsing procedures includes rinsing the Na^+ZP with water through the casing until a desired conductivity is reached.

Claim 19: The method of Claim 17, wherein regenerating the disinfected Na^+ZP includes at least one of flowing the sodium based alkaline solution or the sodium salt solution through the casing (i) at a flowrate of 0.1ml/min to 5ml/min, (ii) at a temperature from about 20°C to about 80°C, or (iii) until eluent sodium solution used to contact the Na^+ZP has a conductivity that equals or substantially equals a conductivity of incoming sodium solution.

Claim 20: The method of Claim 17, wherein the disinfecting agent (i) is a sodium based chemical, such as including NaOCl or (ii) includes isopropyl alcohol ("IPA").

Claim 21: The method of Claim 17, wherein the casing including the refurbished Na^+ZP is replaced within the sorbent cartridge with at least one new and different type of casing.

Claim 22: A sorbent refurbishing device comprising:

a cleaning chamber sized and arranged to accept at least one sorbent cartridge casing for refurbishing;

a disinfecting agent source in fluid communication with the cleaning chamber;

a regeneration solution source in fluid communication with the cleaning chamber;

a water source or water connection in fluid communication with the cleaning chamber;

at least one pump positioned and arranged to pump at least one of disinfecting agent, regeneration solution, or water to the cleaning chamber;

at least one first valve located between the disinfecting agent source and the cleaning chamber;

at least one second valve located between the regeneration solution source and the cleaning chamber;

at least one third valve located between the water source or water connection and the cleaning chamber; and

a control unit configured to operate the at least one pump, the at least one first valve, the at least one second valve and the at least one third valve to perform a refurbishing procedure on the at least one cartridge casing,

wherein the cleaning chamber is configured to accept the at least one sorbent cartridge in a particular orientation so that a normal treatment fluid direction and an opposite to normal treatment fluid direction is known,

wherein the cleaning chamber provides tapered or conical insert areas to accept the at least one sorbent cartridge casing to prevent leakage and to ensure the at least one sorbent cartridge casing is placed into the cleaning chamber in a desired orientation.

Claim 23: The sorbent refurbishing device of Claim 22, wherein the at least one first valve is positioned and arranged to enable disinfecting agent to be delivered to either of two opposing sides of the cleaning chamber.

Claim 24: The sorbent refurbishing device of Claim 22, wherein the at least one second valve is positioned and arranged to enable regeneration solution to be delivered to either of two opposing sides of the cleaning chamber.

Claim 25: The sorbent refurbishing device of Claim 22, wherein the at least one third valve is positioned and arranged to enable water to be delivered to either of two opposing sides of the cleaning chamber.

Claim 26: The sorbent refurbishing device of Claim 22, which includes at least one of a conductivity sensor, a temperature sensor, or a pH sensor positioned to sense at least one of the disinfecting agent, the regeneration solution or water, the at least one sensor providing an output to the control unit.

Claim 27: The sorbent refurbishing device of Claim 26, wherein the control unit is configured to use the output to control duration of flow of at least one of the disinfecting agent, the regeneration solution or water.

Claim 28: The sorbent refurbishing device of Claim 26, which further includes at least one heating coil, the control unit configured to use the output from the temperature sensor to operate the at least one heating coil.

Claim 29: The sorbent refurbishing device of Claim 22, which further includes a hot air blower under control of the control unit to dry to the at least one sorbent cartridge casing.