[0008] One embodiment of a method for concentrating ammonium from the separated liquor of anaerobic digestate comprising ammonium ions, other cations, and anions using the electrodialysis stack comprises: feeding a separated anaerobic digestate influent into the diluate cell compartments, wherein monovalent cations selectively pass through the cation exchange membranes into the adjacent concentrate cell compartments to provide a concentrate stream that is concentrated in ammonium ions and other monovalent cations, and multivalent cations are selectively retained in the diluate cell compartments to provide a diluate stream; passing the diluate stream out of the electrodialysis stack as a diluate effluent; feeding a first portion of the concentrate stream back into the concentrate cell compartments; feeding a second portion of the concentrate stream into the cathode cell compartment, wherein ammonium ions react with hydroxide produced at the cathode to form ammonia in a cathode stream; recovering the ammonia from the cathode stream; and passing the concentrate stream out of the electrodialysis stack as a concentrate effluent to be further processed by ammonia separation methods and methods of recovering monovalent salts. The extent of concentrating the recovered salts in the concentrate stream is limited by the solubility of the bicarbonate salts of ammonium, potassium and sodium.

[0008a] In one aspect, there is provided a method for recovering ammonia, monovalent salts or both from separated anaerobic digestate comprising ammonium ions, other cations, and anions using an electrodialysis stack comprising:

an anode;

a cathode;

one or more monovalent-selective cation exchange membranes; and

one or more anion exchange membranes;

wherein the monovalent-selective cation exchange membranes and the anion exchange membranes are disposed in an alternating arrangement between the anode and the cathode, such that a plurality of cell compartments are defined in the stack, the cell compartments comprising: a cathode cell compartment defined between the cathode and an anion exchange membrane; an anode cell compartment defined between the anode and a monovalent-selective cation exchange membrane; a plurality of diluate cell compartments, each defined between a monovalent-selective cation exchange membrane and its adjacent anion exchange membrane; and a plurality of concentrate cell compartments, each defined

between an anion exchange membrane and its adjacent monovalent-selective cation exchange membrane;

the method comprising:

(a) feeding a separated anaerobic digestate influent into the diluate cell compartments, wherein monovalent cations selectively pass through the cation exchange membranes into the concentrate cell compartments to provide a concentrate stream that is concentrated in ammonium ions and other monovalent cations, and multivalent cations are selectively retained in the diluate cell compartments to provide a diluate stream;

(b) passing the diluate stream out of the electrodialysis stack as a diluate effluent, such that precipitation of salts of the multivalent cations in the electrodialysis stack is avoided;

(c) recycling the concentrate stream back into the concentrate cell compartments to further increase the concentration of ammonium ions and other monovalent cations in the concentrate effluent;

(d) passing the concentrate stream out of the electrodialysis stack as a concentrate effluent; and

(e) recovering one or more salts of the monovalent cations from the concentrate effluent.

[0009] One embodiment of a system for recovering ammonia from the separated liquor of anaerobic digestate comprising ammonium ions, other cations, and anions, comprises: an electrodialysis stack, as described above; an anaerobic digestate source configured to feed a separated anaerobic digestate influent into the diluate cell compartments; feeding a portion of the concentrate stream into the cathode cell compartment; and an ammonia separator configured to accept an effluent from the cathode cell compartment and to separate ammonia from the effluent. The ammonia separation may comprise air or steam sparging of the concentrate effluent, with recovery of either ammonia by refrigeration or ammonium sulfate, nitrate or phosphate by passing the ammonia stream through solutions of the appropriate acids: sulfuric, nitric or phosphoric acids, respectively.

[0009a] In another aspect, there is provided a system for recovering ammonia from anaerobic digestate comprising ammonium ions, other cations, and anions, the system comprising:

(a) an electrodialysis stack comprising:

an anode;

a cathode;

one or more monovalent-selective cation exchange membranes; and

one or more anion exchange membranes;

wherein the monovalent-selective cation exchange membranes and the anion exchange membranes are disposed in an alternating arrangement between the anode and the cathode, such that a plurality of cell compartments are defined in the stack, the cell compartments comprising: a cathode cell compartment defined between the cathode and an anion exchange membrane; an anode cell compartment defined between the anode and a monovalent-selective cation exchange membrane; a plurality of diluate cell compartments, each defined between a monovalent-selective cation exchange membrane and its adjacent anion exchange membrane; and a plurality of concentrate cell compartments, each defined between an anion exchange membrane and its adjacent monovalent-selective cation exchange membrane;

(b) an anaerobic digestate source configured to feed a separated anaerobic digestate influent into the diluate cell compartments; and

(c) an ammonia separator configured to accept an effluent from the cathode cell compartment and to separate ammonia from the effluent.

[0010] One embodiment of a system for recovering ammonium salts includes the refrigeration of the concentrated effluent of the electrodialysis stack, which has been concentrated in both ammonium and bicarbonate ions, to produce solid ammonium bicarbonate precipitates.

[0010a] In another aspect, there is provided a method for recovering cation salts, monovalent anion salts or both from separated anaerobic digestate comprising cations, bicarbonate anions, other monovalent anions, and multivalent anions using an electrodialysis stack comprising:

an anode;

a cathode;

one or more monovalent-selective anion exchange membranes; and

one or more cation exchange membranes;

wherein the monovalent-selective anion exchange membranes and the cation exchange membranes are disposed in an alternating arrangement between the anode and the cathode, such that a plurality of cell compartments are defined in the stack, the cell compartments comprising: a cathode cell compartment defined between the cathode and a monovalent-selective anion exchange membrane; an anode cell compartment defined between the anode and a cation exchange membrane; a plurality of diluate cell compartments, each defined between a monovalent-selective anion exchange membrane and its adjacent cation exchange membrane; and a plurality of concentrate cell compartments, each defined between an cation exchange membrane and its adjacent monovalent-selective anion exchange membrane;

the method comprising:

(a) feeding a separated anaerobic digestate influent into the diluate cell compartments, wherein bicarbonate ions and other monovalent anions selectively pass through the monovalent-selective anion exchange membranes into the concentrate cell compartments to provide a concentrate stream that is concentrated in bicarbonate ions and other monovalent anions, and multivalent anions are selectively retained in the diluate cell compartments to provide a diluate stream;

(b) passing the diluate stream out of the electrodialysis stack as a diluate effluent;

(c) feeding at least a portion of the concentrate stream into the anode cell compartment, wherein the bicarbonate ion concentration is reduced via acidification to provide an anode cell effluent that has a reduced bicarbonate ion concentration;

(d) passing the anode cell effluent out of the electrodialysis stack; and

(e) recovering one or more salts of the cations and other monovalent anions from the anode cell effluent.

[0011] Another embodiment includes the low-temperature distillation of the concentrated effluent of the electrodialysis stack, which has been concentrated in both ammonium and carbonate ions, at 50 to 80 °C to volatilize ammonium bicarbonate, which is recovered in pure form upon cooling to ambient temperature.

[0012] Another embodiment includes the recirculation of one part of the concentrate stream stripped of ammonium and ammonia back into the concentrate stream and the treatment of the second part of the stripped stream for recovery of potassium, phosphate and other desired ions in the separated anaerobic digestate concentrated by the electrodialysis system.

[0013] Other principal features and advantages of the disclosure will become apparent to those skilled in the art upon review of the following drawings, the detailed description, and the appended claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] Illustrative embodiments of the invention will hereafter be described with reference to the accompanying drawings, wherein like numerals denote like elements.

[0015] FIG. 1 is a table listing examples of anaerobic digestate influents that can be processed in the electrodialysis stacks.

[0016] FIG. 2A is a schematic diagram of a single-phase anaerobic digestion system.

[0017] FIG. 2B is a schematic diagram of a multiphase anaerobic digestion system.

[0018] FIG. 3 is a schematic diagram of an electrodialysis stack comprising a series of monovalent-selective cation exchange membranes and monovalent-selective anion exchange membranes.

[0019] FIG. 4 is a process flow diagram illustrating the processing flow used in an electrodialysis stack.

[0020] FIG. 5 is a graph showing the ammonium bicarbonate concentration in a recirculating concentrate stream as a function of time for anaerobic digestate influents having different initial ammonium bicarbonate concentrations.

(c) feeding at least a portion of the concentrate stream into the anode cell compartment, wherein the bicarbonate ion concentration is reduced via acidification to provide an anode cell effluent that has a reduced bicarbonate ion concentration;

(d) passing the anode cell effluent out of the electrodialysis stack; and

(e) recovering one or more salts of the cations and other monovalent anions from the anode cell effluent.

21. The method of claim 1, wherein the separated anaerobic digestate influent is from an anaerobic digestion system used in a municipal sewage treatment facility.

22. The method of claim 1, wherein the separated anaerobic digestate influent is the effluent from a mesophiclic anaerobic digester that digests a primary sludge, a waste activated sludge, or an effluent from an upstream thermophilic digester.

23. The system of claim 16, wherein the anaerobic digestate source is an anaerobic digestion system used in a municipal sewage treatment facility.

24. The method of claim 16, wherein the anaerobic digestate source is a mesophiclic anaerobic digester that digests a primary sludge, a waste activated sludge, or an effluent from an upstream thermophilic digester.