

CLAIMS

1. A process for removing a dissolved species from an aqueous inflow stream, the dissolved species comprising a dissolved nitrogen and/or a dissolved
5 phosphorous and/or a dissolved potassium species, the process comprising:
segregating the aqueous inflow stream into a plurality of reactor inflow streams, and directing the plurality of reactor inflow streams upwardly into the base of a reaction conduit segment in a reactor vessel so as to create a turbulent upward flow in the reaction conduit;
10 injecting a precipitating agent into the base of the reaction conduit under conditions maintained in the reaction conduit so as to provide a supersaturated concentration of a reaction product of the precipitating agent reacting with the dissolved species, providing a saturation index of at least 2 for the reaction product, the reaction product forming a solid precipitant species entrained
15 in an upward reaction conduit fluid flow;
directing the upward reaction conduit fluid flow to a contiguous clarifier segment of the reactor, the clarifier segment of the reactor being dimensioned to reduce the upward flow rate of the upward reaction conduit fluid flow, and maintaining an upward clarified fluid flow rate in the clarifier so as to
20 permit entrained solid precipitant species to descend in the clarifier segment of the reactor and return to the reaction conduit while a clarified discharge fluid flow continues to flow upwardly out of the clarifier segment of the reactor;
maintaining conditions in the reactor to permit the progressive agglomeration of the precipitant species to form agglomerated granules of a size
25 and density sufficient to cause the agglomerated granules to settle towards the base of the reaction conduit in the presence of the turbulent upward reaction conduit fluid flow;
injecting an upward channeled fluid flow through a channel in fluid communication with the base of the reaction conduit, the channel being
30 dimensioned to permit metering of the upward channeled fluid flow so as to permit agglomerated granules of a selected size and density to descend through the channel while returning un-selected precipitant species upwardly to the reaction

conduit, thereby segregating a sized solid granule product by elutriation that descends through the channel into a contiguous pellet hopper sized to accommodate a settled volume of the sized solid granule product.

5 2. The process of claim 1, further comprising periodically restricting the upward
channeled fluid flow in the channel and downwardly releasing the contents of the
hopper, to collect the desired solid granule product.

3. The process of claim 1 or 2, further comprising recirculating a portion of the
10 clarified fluid flow from the clarifier to the hopper to mediate the upward channeled
fluid flow through the channel.

4. The process of any one of claims 1 to 3, further comprising providing an
upward hopper fluid flow in the hopper that mediates the upward channeled fluid
15 flow in the channel, and sizing the hopper so that the upward hopper fluid flow is
less than the upward channeled fluid flow.

5. The process of any one of claims 1 to 4, further comprising segregating the
aqueous inflow stream into the plurality of reactor inflow streams in a manifold in
20 fluid communication with the reaction conduit.

6. The process of any one of claims 1 to 5, wherein the precipitating agent
comprises an alkali, a magnesium salt, MgCl_2 , MgSO_4 , MgO , $\text{Mg}(\text{OH})_2$, magnesite,
brucite, a combustion bottom ash or a fly ash.

25 7. The process of any one of claims 1 to 6, wherein the desired solid granule
product comprises one or more of: struvite, K-struvite, calcium ammonium phosphate
 CaNH_4PO_4 , and/or hydroxyapatite $\text{Ca}_5(\text{PO}_4)_3(\text{OH})$, brushite $\text{CaHPO}_4 \cdot 2\text{H}_2\text{O}$, newberyite
 $\text{MgHPO}_4 \cdot 3\text{H}_2\text{O}$, and/or magnesium phosphate $\text{Mg}_3(\text{PO}_4)_2$.

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8. The process of any one of claims 1 to 7, wherein the inflow stream comprises up to 1%, 2%, 3%, 4% or 5% by weight suspended solids, optionally wherein 50-95% of the suspended solids in the inflow stream pass through the reactor to the clarified discharge fluid flow.
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9. The process of any one of claims 1 to 8, wherein the channel has an average channel cross-sectional area C_{xarea} , the pellet hopper has an average pellet hopper cross sectional area PH_{xarea} and the reaction conduit has an average conduit cross sectional area RC_{xarea} , wherein $C_{xarea} < PH_{xarea}$, and $C_{xarea} < RC_{xarea}$.
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10. The process of any one of claims 1 to 9, further comprising collecting the sized solid granule product on a sieve; optionally further washing the sized solid granule product on the sieve; optionally drying the sized solid granule product on the sieve.
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11. The process of any one of claims 1 to 10, wherein the purity of the desired solid granule product is at least 70%, 75%, 80%, 90% or 95%.
12. The process of any one of claims 1 to 11, wherein the upward channeled fluid flow rate is maintained at about 10%, optionally in a range of 5-50%, of the upward reaction conduit fluid flow rate.
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13. The process of any one of claims 1 to 12, wherein the initial saturation index SI at the base of the reaction conduit for the reaction product is maintained in the range of 2.0-3.0, optionally at about 2.5.
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14. The process of any one of claims 1 to 13, wherein the upward reaction conduit fluid flow rate is maintained between 20-80 cm/min, optionally approximately 50 cm/min.
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15. The process of any one of claims 1 to 14, wherein a hydraulic retention time in the reaction conduit is maintained between 1-10 min, optionally between 2-5 min.
16. The process of any one of claims 1 to 15, wherein the upward clarified fluid
5 flow rate is maintained between about 1-5 cm/min, optionally at about 2 cm/min.
17. The process of any one of claims 1 to 16, wherein the clarifier is a frustum shaped clarified, optionally where the frustum shaped clarifier comprises sloped walls having a slope angle of from about 45-85°, optionally from about 60-70°.
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18. The process of any one of claims 1 to 17, wherein the removal of one or more of the dissolved species from an aqueous inflow stream to provide the clarified discharge fluid flow is at least 60%, 70%, 80% or 89%.
- 15 19. The process of any one of claims 1 to 18, wherein sized solid granule product has an average product size, and the average product size is from about 1-2 mm.
- 20 20. The process of any one of claims 1 to 19, wherein the sized solid granule product has a product purity of at least about 60%, 70%, 80%, 90% or 96%.
21. A reactor system operable to remove a dissolved species from an aqueous inflow stream, the dissolved species comprising a dissolved nitrogen and/or a dissolved phosphorous and/or a dissolved potassium species, the reactor system
25 comprising:
a manifold segregating an aqueous inflow stream into a plurality of reactor inflow streams, and directing the plurality of reactor inflow streams upwardly into a base of a reaction conduit segment in a reactor vessel in fluid communication with the manifold, so as to create a turbulent upward flow in the reaction conduit;
30 a precipitating agent inlet port in fluid communication with the base of the reaction conduit, adapted for injecting a precipitating agent into the base of the

reaction conduit under the control of reactor system controls adapted to maintain conditions in the reaction conduit so as to provide a supersaturated concentration of a reaction product of the precipitating agent reacting with the dissolved species, providing a saturation index of at least 2 for the reaction product, the reaction
5 product forming a solid precipitant species entrained in an upward reaction conduit fluid flow;

a clarifier segment of the reactor, upwardly contiguous with the reaction segment, the clarifier segment of the reactor being dimensioned relative to the reaction segment so as to reduce an upward flow rate of an upward reaction
10 conduit fluid flow directed into the clarifier from the reaction segment, under the control of clarifier system controls operable to maintain an upward clarified fluid flow rate in the clarifier so as to permit entrained solid precipitant species to descend in the clarifier segment of the reactor and return to the reaction conduit while a clarified discharge fluid flow continues to flow upwardly out of the clarifier segment
15 of the reactor;

wherein the reactor system controls are operable to maintain conditions in the reactor to permit the progressive agglomeration of the precipitant species to form agglomerated granules of a size and density sufficient to cause the agglomerated granules to settle towards the base of the reaction conduit in the
20 presence of the turbulent upward reaction conduit fluid flow;

a channel in fluid communication with the base of the reaction conduit having a channel fluid source to provide an upward channeled fluid flow through the channel into the base of the reaction conduit, the channel being dimensioned to permit metering of the upward channeled fluid flow so as to permit agglomerated
25 granules of a selected size and density to descend through the channel while returning un-selected precipitant species upwardly to the reaction conduit, thereby segregating a sized solid granule product by elutriation that descends through the channel into a contiguous pellet hopper sized to accommodate a settled volume of sized solid granule product.

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22. The reactor system of claim 21, further comprising an intake pump upstream of the manifold to provide a pressurized aqueous inflow stream.
23. The reactor system of claim 21 or 22, further comprising a jacket on the
5 clarifier configured to collect the clarified discharge fluid flow.
24. The reactor system of any one of claims 21 to 23, further comprising injection nozzles directing the plurality of reactor inflow streams upwardly into the base of the reaction conduit; optionally wherein the injection nozzles are elevated
10 above a bottom portion of the reaction conduit; optionally wherein there are at least 2, 3, 4, 5 or 6 injection nozzles; optionally wherein the injection nozzles are generally evenly distributed throughout a cross-sectional area at the base of the reaction conduit; optionally wherein a superficial upflow velocity is provided inside each nozzle of between 5-15 m/s, or about 10 m/s.
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25. The reactor system of any one of claims 21 to 24, further comprising a screen positioned in the aqueous inflow stream before the aqueous inflow stream enters the manifold; optionally, wherein the screen has a smaller mesh than the diameter of the injection nozzles.
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26. The reactor system of any one of claims 21 to 25, wherein the precipitating agent is dosed in close proximity to the injection nozzles.
27. The reactor system of any one of claims 21 to 26, for use in carrying out the
25 process of any one of claims 1 to 20.