SCALEABLE INLINE BUFFER DILUTION SCHEME

FIELD OF THE DISCLOSURE

[0001] The present disclosure generally relates to inline buffer dilution systems and, more particularly, to an inline buffer dilution system that is scalable across a range of fluid flows.

BACKGROUND

[0002] It is common to mix two or more liquids together in order to yield a desired concentration or other characteristics (e.g., pH, conductivity, optical density, refractive index, etc.) of the constituent liquids. Indeed, this mixing, which may be referred to as blending, is fundamental to many industrial segments. As an example, blending systems are used to create blended liquids that are provided to chromatography columns in order to permit the separation of mixtures for analysis or purification.

SUMMARY

[0002a] According to a first aspect of the present invention, there is provided an inline buffer dilution system, comprising:

a first flow control valve adapted to communicate with a vessel comprising a supply of diluent liquid;

a second flow control valve adapted to communicate with a first vessel comprising a supply of a first buffer;

a third flow control valve adapted to communicate with a second vessel comprising a supply of a second buffer;

a mixing pump fluidly connected to the first, second, and third flow control valves and configured to receive an amount of the diluent liquid, the first buffer, and the second buffer via the first, second, and third flow control valves, respectively, the mixing pump further configured

to mix the amount of the diluent liquid, the first buffer, and the second buffer to produce a diluted buffer solution;

a backpressure control valve arranged downstream of the mixing pump and configured to generate a backpressure that promotes mixing within the mixing pump; and

a controller communicatively connected to the mixing pump and the backpressure control valve, the controller configured to control the backpressure generated by the backpressure control valve based on the amount of the diluent liquid, the first buffer, and the second buffer being mixed in the mixing pump, such that the mixing pump yields a minimum mixing threshold across a range of fluid flows,

wherein the controller is configured to restrict a flow of the diluent liquid through the first flow control valve, thereby creating a negative pressure upstream of the mixing pump that drives the supply of the first buffer and the supply of the second buffer through the second flow control valve and the third flow control valve, respectively, and to the mixing pump.

[0002b] According to a second aspect of the present invention, there is provided an inline buffer dilution system, comprising:

a first flow control valve adapted to communicate with a vessel comprising a supply of diluent liquid;

a second flow control valve adapted to communicate with a first vessel comprising a supply of a first buffer;

a third flow control valve adapted to communicate with a second vessel comprising a supply of a second buffer;

a mixing pump fluidly connected to the first, second, and third flow control valves and configured to receive an amount of the diluent liquid, the first buffer, and the second buffer via the first, second, and third flow control valves, respectively, the mixing pump further configured to mix the amount of the diluent liquid, the first buffer, and the second buffer to produce a diluted buffer solution;

a backpressure control valve arranged downstream of the mixing pump and configured to generate a backpressure that promotes mixing within the mixing pump;

a controller communicatively connected to the mixing pump and the backpressure control valve, the controller configured to control the backpressure generated by the backpressure control valve based on the amount of the diluent liquid, the first buffer, and the second buffer being mixed in the mixing pump, such that the mixing pump yields a minimum mixing threshold across a range of fluid flows; and

an additional flow control valve arranged between the mixing pump and the backpressure control valve, the controller configured to control a pressure differential across the additional flow control valve.

[0002c] According to a third aspect of the present invention, there is provided an inline buffer dilution system, comprising:

a vessel comprising a supply of diluent liquid;

a first vessel comprising a supply of a first buffer, the first vessel pressurized using only atmospheric pressure;

a second vessel comprising a supply of a second buffer, the second vessel pressurized using only atmospheric pressure;

a first flow control valve arranged downstream of and configured to communicate with the supply of diluent liquid;

a second flow control valve arranged downstream of and configured to communicate with the first vessel comprising the supply of the first buffer;

a third flow control valve arranged downstream of and configured to communicate with the second vessel comprising the supply of the second buffer;

a mixing pump fluidly connected to the first, second, and third flow control valves and configured to receive an amount of the diluent liquid, the first buffer, and the second buffer via the first, second, and third flow control valves, respectively, the mixing pump further configured to mix the amount of the diluent liquid, the first buffer, and the second buffer to produce a diluted buffer solution;

a backpressure control valve arranged downstream of the mixing pump and configured to generate a backpressure that promotes mixing within the mixing pump;

a controller communicatively connected to the mixing pump and the backpressure control valve, the controller configured to control the backpressure generated by the backpressure control valve based on the amount of the diluent liquid, the first buffer, and the second buffer being mixed in the mixing pump, such that the mixing pump yields a minimum mixing threshold across a range of fluid flows; and

an additional flow control valve arranged between the mixing pump and the backpressure control valve, the controller configured to control a pressure differential across the additional flow control valve.

[0002d] According to a fourth aspect of the present invention, there is provided an inline buffer dilution system, comprising:

a vessel comprising a supply of diluent liquid;

a first vessel comprising a supply of a first buffer, the first vessel pressurized using only atmospheric pressure;

a second vessel comprising a supply of a second buffer, the second vessel pressurized using only atmospheric pressure;

a first flow control valve arranged downstream of and configured to communicate with the supply of diluent liquid;

a second flow control valve arranged downstream of and configured to communicate with the first vessel comprising the supply of the first buffer;

a third flow control valve arranged downstream of and configured to communicate with the second vessel comprising the supply of the second buffer;

a mixing pump fluidly connected to the first, second, and third flow control valves and configured to receive an amount of the diluent liquid, the first buffer, and the second buffer via the first, second, and third flow control valves, respectively, the mixing pump further configured to mix the amount of the diluent liquid, the first buffer, and the second buffer to produce a diluted buffer solution;

a backpressure control valve arranged downstream of the mixing pump and configured to generate a backpressure that promotes mixing within the mixing pump; and

a controller communicatively connected to the mixing pump and the backpressure control valve,

the controller configured to control the backpressure generated by the backpressure control valve based on the amount of the diluent liquid, the first buffer, and the second buffer being mixed in the mixing pump, such that the mixing pump yields a minimum mixing threshold across a range of fluid flows,

wherein the controller is configured to restrict a flow of the diluent liquid through the first flow control valve, thereby creating a negative pressure upstream of the mixing pump that drives the supply of the first buffer and the supply of the second buffer through the second flow control valve and the third flow control valve, respectively, and to the mixing pump.

[0002e] According to a fifth aspect of the present invention, there is provided a method of producing a diluted buffer solution across a range of fluid flows, comprising:

providing a first flow control valve adapted to communicate with a vessel comprising a supply of diluent liquid, a second flow control valve adapted to communicate with a first vessel comprising a supply of a first buffer, and a third flow control valve adapted to communicate with a second vessel comprising a supply of a second buffer;

directing an amount of the diluent liquid, the first buffer, and the second buffer to a mixing pump via the first, second, and third flow control valves, respectively;

mixing the amount of the diluent liquid, the first buffer, and the second buffer in the mixing pump, thereby producing a diluted buffer solution;

generating, via a backpressure control valve arranged downstream of the mixing pump, a backpressure that promotes mixing within the mixing pump; and

controlling, via a controller communicatively connected to the mixing pump and the backpressure control valve, the backpressure generated by the backpressure control valve based on the amount of the diluent liquid, the first buffer, and the second buffer being mixed in the mixing pump, such that the mixing pump yields a minimum mixing threshold across a range of fluid flows,

wherein the controller is configured to restrict a flow of the diluent liquid through the first flow control valve, thereby creating a negative pressure upstream of the mixing pump that directs the supply of the first buffer and the supply of the second buffer through the second flow control valve and the third flow control valve, respectively, and to the mixing pump.

BRIEF DESCRIPTION OF THE DRAWINGS

[0003] The features of this disclosure which are believed to be novel are set forth with particularity in the appended claims. The present disclosure may be best understood by reference to the following description taken in conjunction with the accompanying drawings, in which like reference numerals identify like elements in the several figures, in which:

[0004] FIG. 1 is a schematic illustration of an example of an inline buffer dilution system constructed in accordance with the teachings of the present disclosure;

[0005] FIG. 2 is a perspective view of the mixing pump employed in the inline buffer dilution system of FIG. 1; and

[0006] FIG. 3 is a cross-sectional view of the mixing pump of FIG. 2.

CLAIMS

~~1. An inline buffer dilution system, comprising:~~

~~a first flow control valve adapted to communicate with a vessel comprising a supply of diluent liquid;~~

~~a second flow control valve adapted to communicate with a first vessel comprising a supply of a first buffer;~~

~~a third flow control valve adapted to communicate with a second vessel comprising a supply of a second buffer;~~

~~a mixing pump fluidly connected to the first, second, and third flow control valves and configured to receive an amount of the diluent liquid, the first buffer, and the second buffer via the first, second, and third flow control valves, respectively, the mixing pump further configured to mix the amount of the diluent liquid, the first buffer, and the second buffer to produce a diluted buffer solution;~~

~~a backpressure control valve arranged downstream of the mixing pump and configured to generate a backpressure that promotes mixing within the mixing pump; and~~

~~a controller communicatively connected to the mixing pump and the backpressure control valve, the controller configured to control the backpressure generated by the backpressure control valve based on the amount of the diluent liquid, the first buffer, and the second buffer being mixed in the mixing pump, such that the mixing pump yields a minimum mixing threshold across a range of fluid flows.~~

~~2. The inline buffer dilution system of claim 1, wherein the backpressure control valve is configured to generate a first backpressure when the mixing pump mixes a first amount of the diluent liquid, the first buffer, and the second buffer, and wherein the backpressure control valve is configured to generate a second backpressure different from the first backpressure when the mixing pump mixes a second amount of the diluent liquid, the first buffer, and the second buffer.~~

~~3. The inline buffer dilution system of claim 2, wherein when the second amount is less than the first amount, the second backpressure is less than the first backpressure.~~

4. The inline buffer dilution system of any one of claims 1 to 3, wherein the controller is configured to restrict a flow of the diluent liquid through the first flow control valve, thereby creating a negative pressure upstream of the mixing pump that drives the supply of the first buffer solution and the supply of the second buffer solution through the second flow control valve and the third flow control valve, respectively, and to the mixing pump.

5. The inline buffer dilution system of any one of claims 1 to 4, further comprising an additional flow control valve arranged between the mixing pump and the backpressure control valve, the controller configured to control a pressure differential across the additional flow control valve.

6. The inline buffer dilution system of any one of claims 1 to 5, further comprising the first vessel comprising the supply of the first buffer and the second vessel comprising the supply of the second buffer, wherein each of the first vessel and the second vessel is pressurized using only atmospheric pressure.

7. The inline buffer dilution system of any one of claims 1 to 6, further comprising a conductivity sensor arranged between the mixing pump and the backpressure control valve, the conductivity sensor configured to detect the conductivity of the diluted buffer solution produced by the mixing pump.

8. The inline buffer dilution system of any one of claims 1 to 7, further comprising a pH sensor arranged between the mixing pump and the backpressure control valve, the pH sensor configured to detect the pH of the diluted buffer solution produced by the mixing pump.

9. The inline buffer dilution system of any one of claims 1 to 8, further comprising a first flowmeter fluidly coupled to the second flow control valve and a second flowmeter fluidly coupled to the third flow control valve, the controller communicatively connected to the first and second flowmeters and configured to obtain from the first and second flowmeters data indicative of the fluid flowing through the second and third flow control valves, respectively.

10. An inline buffer dilution system, comprising:

a vessel comprising a supply of diluent liquid;

a first vessel comprising a supply of a first buffer, the first vessel pressurized using only atmospheric pressure;

a second vessel comprising a supply of a second buffer, the second vessel pressurized using only atmospheric pressure;

a first flow control valve arranged downstream of and configured to communicate with the supply of diluent liquid;

a second flow control valve arranged downstream of and configured to communicate with the first vessel comprising the supply of the first buffer;

a third flow control valve arranged downstream of and configured to communicate with the second vessel comprising the supply of the second buffer;

a mixing pump fluidly connected to the first, second, and third flow control valves and configured to receive an amount of the diluent liquid, the first buffer, and the second buffer via the first, second, and third flow control valves, respectively, the mixing pump further configured to mix the amount of the diluent liquid, the first buffer, and the second buffer to produce a diluted buffer solution;

a backpressure control valve arranged downstream of the mixing pump and configured to generate a backpressure that promotes mixing within the mixing pump; and

a controller communicatively connected to the mixing pump and the backpressure control valve, the controller configured to control the backpressure generated by the backpressure control valve based on the amount of the diluent liquid, the first buffer, and the second buffer being mixed in the mixing pump, such that the mixing pump yields a minimum mixing threshold across a range of fluid flows.

11. The inline buffer dilution system of claim 10, wherein the backpressure control valve is configured to generate a first backpressure when the mixing pump mixes a first amount of the diluent liquid, the first buffer, and the second buffer, and wherein the backpressure control valve is configured to generate a second backpressure different from the first backpressure when the mixing pump mixes a second amount of the diluent liquid, the first buffer, and the second buffer.

~~12. The inline buffer dilution system of claim 11, wherein when the second amount is less than the first amount, the second backpressure is less than the first backpressure.~~

~~13. The inline buffer dilution system of any one of claims 10 to 12, wherein the controller is configured to restrict a flow of the diluent liquid through the first flow control valve, thereby creating a negative pressure upstream of the mixing pump that drives the supply of the first buffer solution and the supply of the second buffer solution through the second flow control valve and the third flow control valve, respectively, and to the mixing pump.~~

~~14. The inline buffer dilution system of any one of claims 10 to 13, further comprising an additional flow control valve arranged between the mixing pump and the backpressure control valve, the controller configured to control a pressure differential across the additional flow control valve.~~

~~15. The inline buffer dilution system of any one of claims 10 to 14, further comprising a conductivity sensor arranged between the mixing pump and the backpressure control valve, the conductivity sensor configured to detect the conductivity of the diluted buffer solution produced by the mixing pump.~~

~~16. The inline buffer dilution system of any one of claims 10 to 15, further comprising a pH sensor arranged between the mixing pump and the backpressure control valve, the pH sensor configured to detect the pH of the diluted buffer solution produced by the mixing pump.~~

~~17. The inline buffer dilution system of any one of claims 10 to 16, wherein the first vessel comprises a first container housing the supply of the first buffer and the second vessel comprises a second container housing the supply of the second buffer, and wherein each of the first and second containers is made from a disposable material.~~

~~18. The inline buffer dilution system of claim 17, wherein the disposable material comprises a gamma stable plastic material.~~

~~19. A method of producing a diluted buffer solution across a range of fluid flows, comprising:~~

~~providing a first flow control valve adapted to communicate with a vessel comprising a supply of diluent liquid, a second flow control valve adapted to communicate with a first vessel comprising a supply of a first buffer, and a third flow control valve adapted to communicate with a second vessel comprising a supply of a second buffer;~~

~~directing an amount of the diluent liquid, the first buffer, and the second buffer to a mixing pump;~~

~~mixing the amount of the diluent liquid, the first buffer, and the second buffer in the mixing pump, thereby producing a diluted buffer solution;~~

~~generating, via a backpressure control valve arranged downstream of the mixing pump, a backpressure that promotes mixing within the mixing pump; and~~

~~controlling, via a controller communicatively connected to the mixing pump and the backpressure control valve, the backpressure generated by the backpressure control valve based on the amount of the diluent liquid, the first buffer, and the second buffer being mixed in the mixing pump.~~

~~20. The method of claim 19, wherein the controlling comprises decreasing the backpressure generated by the backpressure control valve when the amount of the diluent liquid, the first buffer, and the second buffer being mixed in the mixing pump decreases.~~

1. An inline buffer dilution system, comprising:

a first flow control valve adapted to communicate with a vessel comprising a supply of diluent liquid;

a second flow control valve adapted to communicate with a first vessel comprising a supply of a first buffer;

a third flow control valve adapted to communicate with a second vessel comprising a supply of a second buffer;

a mixing pump fluidly connected to the first, second, and third flow control valves and configured to receive an amount of the diluent liquid, the first buffer, and the second buffer via the first, second, and third flow control valves, respectively, the mixing pump further configured to mix the amount of the diluent liquid, the first buffer, and the second buffer to produce a diluted buffer solution;

a backpressure control valve arranged downstream of the mixing pump and configured to generate a backpressure that promotes mixing within the mixing pump; and

a controller communicatively connected to the mixing pump and the backpressure control valve, the controller configured to control the backpressure generated by the backpressure control valve based on the amount of the diluent liquid, the first buffer, and the second buffer being mixed in the mixing pump, such that the mixing pump yields a minimum mixing threshold across a range of fluid flows,

wherein the controller is configured to restrict a flow of the diluent liquid through the first flow control valve, thereby creating a negative pressure upstream of the mixing pump that drives the supply of the first buffer and the supply of the second buffer through the second flow control valve and the third flow control valve, respectively, and to the mixing pump.

2. The inline buffer dilution system of claim 1, wherein the backpressure control valve is configured to generate a first backpressure when the mixing pump mixes a first amount of the diluent liquid, the first buffer, and the second buffer, and wherein the backpressure control valve is configured to generate a second backpressure different from the first backpressure when the mixing pump mixes a second amount of the diluent liquid, the first buffer, and the second buffer.

3. The inline buffer dilution system of claim 2, wherein when the second amount is less than the first amount, the second backpressure is less than the first backpressure.

4. The inline buffer dilution system of claim 1, further comprising the first vessel comprising the supply of the first buffer and the second vessel comprising the supply of the second buffer, wherein each of the first vessel and the second vessel is pressurized using only atmospheric pressure.

5. The inline buffer dilution system of claim 1, further comprising a conductivity sensor arranged between the mixing pump and the backpressure control valve, the conductivity sensor configured to detect the conductivity of the diluted buffer solution produced by the mixing pump.

6. The inline buffer dilution system of claim 1, further comprising a pH sensor arranged between the mixing pump and the backpressure control valve, the pH sensor configured to detect the pH of the diluted buffer solution produced by the mixing pump.

7. The inline buffer dilution system of claim 1, further comprising a first flowmeter fluidly coupled to the second flow control valve and a second flowmeter fluidly coupled to the third flow control valve, the controller communicatively connected to the first and second flowmeters and configured to obtain from the first and second flowmeters data indicative of the fluid flowing through the second and third flow control valves, respectively.

8. An inline buffer dilution system, comprising:

a first flow control valve adapted to communicate with a vessel comprising a supply of diluent liquid;

a second flow control valve adapted to communicate with a first vessel comprising a supply of a first buffer;

a third flow control valve adapted to communicate with a second vessel comprising a supply of a second buffer;

a mixing pump fluidly connected to the first, second, and third flow control valves and configured to receive an amount of the diluent liquid, the first buffer, and the second buffer via the first, second, and third flow control valves, respectively, the mixing pump further configured to mix the amount of the diluent liquid, the first buffer, and the second buffer to produce a diluted buffer solution;

a backpressure control valve arranged downstream of the mixing pump and configured to generate a backpressure that promotes mixing within the mixing pump;

a controller communicatively connected to the mixing pump and the backpressure control valve, the controller configured to control the backpressure generated by the backpressure control valve based on the amount of the diluent liquid, the first buffer, and the second buffer

being mixed in the mixing pump, such that the mixing pump yields a minimum mixing threshold across a range of fluid flows; and

an additional flow control valve arranged between the mixing pump and the backpressure control valve, the controller configured to control a pressure differential across the additional flow control valve.

9. An inline buffer dilution system, comprising:

a vessel comprising a supply of diluent liquid;

a first vessel comprising a supply of a first buffer, the first vessel pressurized using only atmospheric pressure;

a second vessel comprising a supply of a second buffer, the second vessel pressurized using only atmospheric pressure;

a first flow control valve arranged downstream of and configured to communicate with the supply of diluent liquid;

a second flow control valve arranged downstream of and configured to communicate with the first vessel comprising the supply of the first buffer;

a third flow control valve arranged downstream of and configured to communicate with the second vessel comprising the supply of the second buffer;

a mixing pump fluidly connected to the first, second, and third flow control valves and configured to receive an amount of the diluent liquid, the first buffer, and the second buffer via the first, second, and third flow control valves, respectively, the mixing pump further configured to mix the amount of the diluent liquid, the first buffer, and the second buffer to produce a diluted buffer solution;

a backpressure control valve arranged downstream of the mixing pump and configured to generate a backpressure that promotes mixing within the mixing pump;

a controller communicatively connected to the mixing pump and the backpressure control valve, the controller configured to control the backpressure generated by the backpressure control valve based on the amount of the diluent liquid, the first buffer, and the second buffer being mixed in the mixing pump, such that the mixing pump yields a minimum mixing threshold across a range of fluid flows; and

an additional flow control valve arranged between the mixing pump and the backpressure control valve, the controller configured to control a pressure differential across the additional flow control valve.

10. The inline buffer dilution system of claim 9, wherein the backpressure control valve is configured to generate a first backpressure when the mixing pump mixes a first amount of the diluent liquid, the first buffer, and the second buffer, and wherein the backpressure control valve is configured to generate a second backpressure different from the first backpressure when the mixing pump mixes a second amount of the diluent liquid, the first buffer, and the second buffer.

11. The inline buffer dilution system of claim 10, wherein when the second amount is less than the first amount, the second backpressure is less than the first backpressure.

12. The inline buffer dilution system of claim 9, further comprising a conductivity sensor arranged between the mixing pump and the backpressure control valve, the conductivity sensor configured to detect the conductivity of the diluted buffer solution produced by the mixing pump.

13. The inline buffer dilution system of claim 9, further comprising a pH sensor arranged between the mixing pump and the backpressure control valve, the pH sensor configured to detect the pH of the diluted buffer solution produced by the mixing pump.

14. The inline buffer dilution system of claim 9, wherein the first vessel comprises a first container housing the supply of the first buffer and the second vessel comprises a second container housing the supply of the second buffer, and wherein each of the first and second containers is made from a disposable material.

15. The inline buffer dilution system of claim 14, wherein the disposable material comprises a gamma stable plastic material.

16. An inline buffer dilution system, comprising:

a vessel comprising a supply of diluent liquid;

a first vessel comprising a supply of a first buffer, the first vessel pressurized using only atmospheric pressure;

a second vessel comprising a supply of a second buffer, the second vessel pressurized using only atmospheric pressure;

a first flow control valve arranged downstream of and configured to communicate with the supply of diluent liquid;

a second flow control valve arranged downstream of and configured to communicate with the first vessel comprising the supply of the first buffer;

a third flow control valve arranged downstream of and configured to communicate with the second vessel comprising the supply of the second buffer;

a mixing pump fluidly connected to the first, second, and third flow control valves and configured to receive an amount of the diluent liquid, the first buffer, and the second buffer via the first, second, and third flow control valves, respectively, the mixing pump further configured to mix the amount of the diluent liquid, the first buffer, and the second buffer to produce a diluted buffer solution;

a backpressure control valve arranged downstream of the mixing pump and configured to generate a backpressure that promotes mixing within the mixing pump; and

a controller communicatively connected to the mixing pump and the backpressure control valve, the controller configured to control the backpressure generated by the backpressure control valve based on the amount of the diluent liquid, the first buffer, and the second buffer being mixed in the mixing pump, such that the mixing pump yields a minimum mixing threshold across a range of fluid flows,

wherein the controller is configured to restrict a flow of the diluent liquid through the first flow control valve, thereby creating a negative pressure upstream of the mixing pump that drives the supply of the first buffer and the supply of the second buffer through the second flow control valve and the third flow control valve, respectively, and to the mixing pump.

17. A method of producing a diluted buffer solution across a range of fluid flows, comprising:

providing a first flow control valve adapted to communicate with a vessel comprising a supply of diluent liquid, a second flow control valve adapted to communicate with a first vessel

comprising a supply of a first buffer, and a third flow control valve adapted to communicate with a second vessel comprising a supply of a second buffer;

directing an amount of the diluent liquid, the first buffer, and the second buffer to a mixing pump via the first, second, and third flow control valves, respectively;

mixing the amount of the diluent liquid, the first buffer, and the second buffer in the mixing pump, thereby producing a diluted buffer solution;

generating, via a backpressure control valve arranged downstream of the mixing pump, a backpressure that promotes mixing within the mixing pump; and

controlling, via a controller communicatively connected to the mixing pump and the backpressure control valve, the backpressure generated by the backpressure control valve based on the amount of the diluent liquid, the first buffer, and the second buffer being mixed in the mixing pump, such that the mixing pump yields a minimum mixing threshold across a range of fluid flows,

wherein the controller is configured to restrict a flow of the diluent liquid through the first flow control valve, thereby creating a negative pressure upstream of the mixing pump that directs the supply of the first buffer and the supply of the second buffer through the second flow control valve and the third flow control valve, respectively, and to the mixing pump.

18. The method of claim 17, wherein the controlling comprises decreasing the backpressure generated by the backpressure control valve when the amount of the diluent liquid, the first buffer, and the second buffer being mixed in the mixing pump decreases.