1800 seconds for viruses like enterovirus, echovirus 6, coxsackievirus B4 and coxsackievirus B5 to reach 4 log reduction.

It would be desirable to provide alternative methods for inactivating viruses, bacteria or other microorganisms in aqueous solutions. It would be advantageous to provide such methods which do not require the use of high pressures, can be carried out at relatively low cost and/or are not energy intensive.

SUMMARY

In an example, the present disclosure provides a method for inactivating a microorganism in an aqueous solution, the method comprising:

passing bubbles of a gas through the aqueous solution, wherein the gas comprises at least 10% CO_2 by volume and has a temperature of at least 18 °C when the gas first contacts the aqueous solution.

In an aspect, there is provided a method for inactivating a microorganism in an aqueous solution, the method comprising:

passing bubbles of a gas through the aqueous solution, wherein the gas comprises at least 10% CO_2 by volume and has a temperature of at least 18 °C when the gas first contacts the aqueous solution, wherein the aqueous solution is exposed to a pressure of 0.9 to 1.5 bar (0.09 to 0.15 MPa) and bubbles have a diameter of 0.1 mm to 7 mm.

In one example, the microorganism is algae, protozoa, fungi or a spore. In one example, the microorganism is a virus or bacteria. In one example, the aqueous solution comprises a combination of one or more viruses and one or more bacteria, and the method is used to inactivate the viruses and the bacteria in the aqueous solution.

Typically the bubbles are passed through the aqueous solution while the aqueous solution is exposed to atmospheric pressure or about atmospheric pressure. The aqueous solution may, for example, be exposed to a pressure of about 0.9 to 1.5 bar.

In one example, the bubbles have a diameter of 0.1 mm to 7 mm, e.g. 1 mm to 3 mm.

In one example, the gas bubbles occupy from 10% to 60% of the total volume of the combination of the aqueous solution and the bubbles as the bubbles pass through the aqueous solution.

In one example, the bulk temperature of the aqueous solution is from 18 °C to 80 °C, e.g. from 18 °C to 55 °C or from 18 °C to 50 °C.

In one example, the aqueous solution has a bulk temperature of from 18 °C to 55 °C, and the gas has a temperature higher than the bulk temperature of the aqueous solution.

In one example, the aqueous solution comprises a bubble coalescence inhibitor. The bubble coalescence inhibitor may, for example, be selected from the group consisting of NaCl, sucrose, emulsifiers and surfactants.

In an example, the present disclosure provides a system for inactivating microorganisms present in an aqueous solution, the system comprising:

- a gas supply configured to supply gas comprising at least 10% CO_2 by volume, the gas having a temperature of above at least 18 °C;

- a gas-delivery apparatus, the gas-delivery apparatus configured to receive the supply of gas and to deliver the gas into the aqueous solution in the form of bubbles.

In another aspect, there is provided a system when used to inactivate microorganisms present in an aqueous solution, the system comprising:

- a gas supply which supplies gas comprising at least 10% CO_2 by volume, the gas having a temperature of above at least 18 °C;

- a gas-delivery apparatus which receives the supply of gas and delivers the gas into the aqueous solution in the form of bubbles having a diameter of 0.1 mm to 7 mm when the aqueous solution is exposed to a pressure of 0.9 to 1.5 bar (0.09 to 0.15 MPa).

In an example, the present disclosure provides an apparatus for inactivating microorganisms present in an aqueous solution, the apparatus comprising:

- a gas-permeable material, the material having a flow surface at one side thereof that is configured to enable the flow of the aqueous solution across the flow

surface,

- a chamber arranged at an opposite side of the gas-permeable material to supply a gas that inactivates the microorganisms present in the aqueous solution such that the gas is able to pass through the gas-permeable material and into the aqueous solution flowing across the flow surface as gas bubbles.

In another aspect, the present disclosure provides an apparatus for inactivating microorganisms present in an aqueous solution, the apparatus comprising:

- a gas-permeable material, the material having a flow surface at one side thereof that is configured to enable the flow of the aqueous solution across the flow surface,

- a chamber arranged at an opposite side of the gas-permeable material to supply a gas that inactivates the microorganisms present in the aqueous solution such that the gas is able to pass through the gas-permeable material and into the aqueous solution flowing across the flow surface as gas bubbles having a diameter of 0.1 mm to 7 mm when the aqueous solution is exposed to a pressure of 0.9 to 1.5 bar (0.09 to 0.15 MPa).

BRIEF DESCRIPTION OF THE FIGURES

The invention will be further described, by way of example only, with reference to the accompanying drawings, in which:

CLAIMS

1. A method for inactivating a microorganism in an aqueous solution, the method comprising:
passing bubbles of a gas through the aqueous solution, wherein the gas comprises at least 10% CO_2 by volume and has a temperature of at least 18 °C when the gas first contacts the aqueous solution, wherein the aqueous solution is exposed to a pressure of 0.9 to 1.5 bar (0.09 to 0.15 MPa) and bubbles have a diameter of 0.1 mm to 7 mm.

2. The method of claim 1, wherein the microorganism is algae, protozoa, fungi, spore, virus or bacteria.

3. The method of claim 1, wherein the microorganism is a virus or bacteria.

4. The method of any one of claims 1 to 3, wherein the bubbles are passed through the aqueous solution while the aqueous solution is exposed to atmospheric pressure.

5. The method of any one of claims 1 to 4, wherein the gas comprises from 50% to 100% CO_2 by volume.

6. The method of any one of claims 1 to 5, wherein the gas comprises from 10% to 50% CO_2 by volume.

7. The method of any one of claims 1 to 6, wherein the gas has a temperature in excess of 100 °C.

8. The method of any one of claims 1 to 6, wherein the gas has a temperature from 18 °C to 100°C.

9. The method of any one of claims 1 to 8, wherein the bubbles are formed by passing the gas through a porous material in contact with the aqueous solution.

10. The method of any one of claims 1 to 9, wherein the gas bubbles occupy from 10% to 60% of the total volume of the combination of the aqueous solution and the bubbles as the bubbles pass through the aqueous solution.

11. The method of any one of claims 1 to 10, wherein the aqueous solution has a bulk temperature of from 18 °C to 80 °C.

12. The method according to any one of claims 1 to 10, wherein the aqueous solution has a bulk temperature of from 18 °C to 55 °C, and wherein the gas has a temperature higher than the bulk temperature of the aqueous solution.

13. A system when used to inactivate microorganisms present in an aqueous solution, the system comprising:

- a gas supply which supplies gas comprising at least 10% CO_2 by volume, the gas having a temperature of above at least 18 °C;

- a gas-delivery apparatus which receives the supply of gas and delivers the gas into the aqueous solution in the form of bubbles having a diameter of 0.1 mm to 7 mm when the aqueous solution is exposed to a pressure of 0.9 to 1.5 bar (0.09 to 0.15 MPa).

14. The system according to claim 13, wherein the gas-delivery apparatus is a bubble column evaporator.

15. The system according to claim 13 or 14, wherein the gas supply comprises a heater to heat a gas to thereby form the gas having a temperature of above at least 18 °C.

16. The system according to any one of claims 13 to 15, wherein the gas supply further comprises a gas source, the gas source adapted to provide the gas that comprises at least 10% CO_2 by volume.

17. An apparatus for inactivating microorganisms present in an aqueous solution, the apparatus comprising:

- a gas-permeable material, the material having a flow surface at one side thereof that is configured to enable the flow of the aqueous solution across the

flow surface,

- a chamber arranged at an opposite side of the gas-permeable material to supply a gas that inactivates the microorganisms present in the aqueous solution such that the gas is able to pass through the gas-permeable material and into the aqueous solution flowing across the flow surface as gas bubbles having a diameter of 0.1 mm to 7 mm when the aqueous solution is exposed to a pressure of 0.9 to 1.5 bar (0.09 to 0.15 MPa).

18. The apparatus according to claim 17, wherein the flow surface is in the form of a channel.

19. The apparatus according to claim 17 or 18, wherein the flow surface is configured such that gas bubbles pass through the aqueous solution in a direction transverse to the direction of flow of the aqueous solution as it flows across the flow surface.