Investigating the Efficiency of Ultrasound for Controlling Bio-Fouling in Batch Membrane Systems

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Outline

1. Introduction
2. Aim of the research
3. Disruption of microorganism's cell under the effect of ultrasound (theoretical study)
4. Experimental apparatus and measurement techniques
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7. Conclusion and future work

1. Introduction

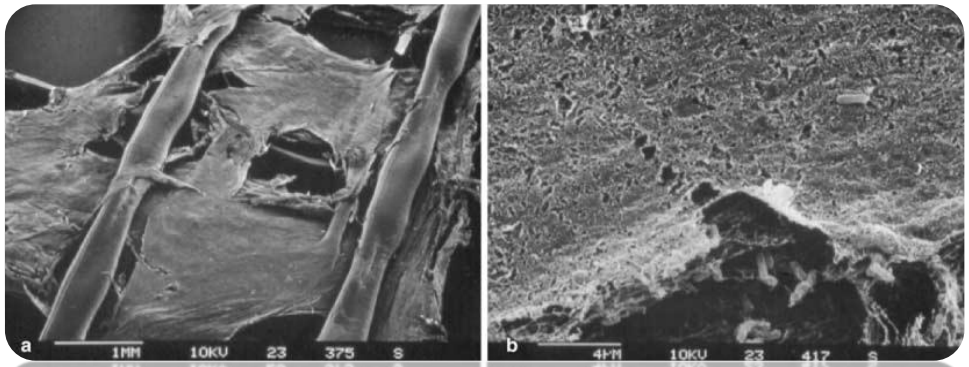
1.1. Importance of membrane technology

It was reported that the estimated number of the people who lack to a healthy drinking water access in the developing countries has reached about one billion, while the number of the people who lack to a sufficient water for sanitation purposes in these countries has reached two billion (Ridoutt and Pfister, 2010).

1.2. Problems encounter membrane technology "Bio-fouling"

1. Deterioration in membrane flux
2. biodegradation of membrane
3. increase in the differential pressure with consequent rise in the feed pressure, causing increase in the salt passage.

What is the solution?



Scanning electron micrograph of biofouling on RO membrane taken by (Flemming,2002)

1.3. Proposed solution

Disinfection

Disinfecting the feed water of the membrane system can be an effective technique to control the formation of bio-fouling (Hori and Matsumoto, 2010).

Chemical methods

1. Health issues
2. Deteriorating membrane materials
3. Low efficiency

UV-light

1. Health issues
2. Recovery of treated microorganisms
3. Low efficiency

Membrane pre-treatment system

1. Fouling and bio-fouling problems

1.4. Ultrasound as a pre-treatment

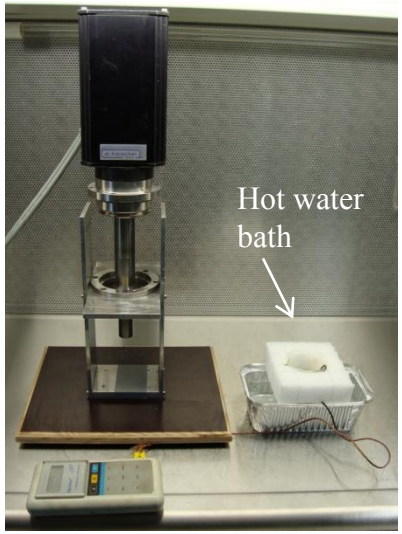
1. Environmentally friendly
2. No reaction with the membrane material
3. high efficiency

Ultrasound treatments

Sonication

Manosonication

Thermosonication

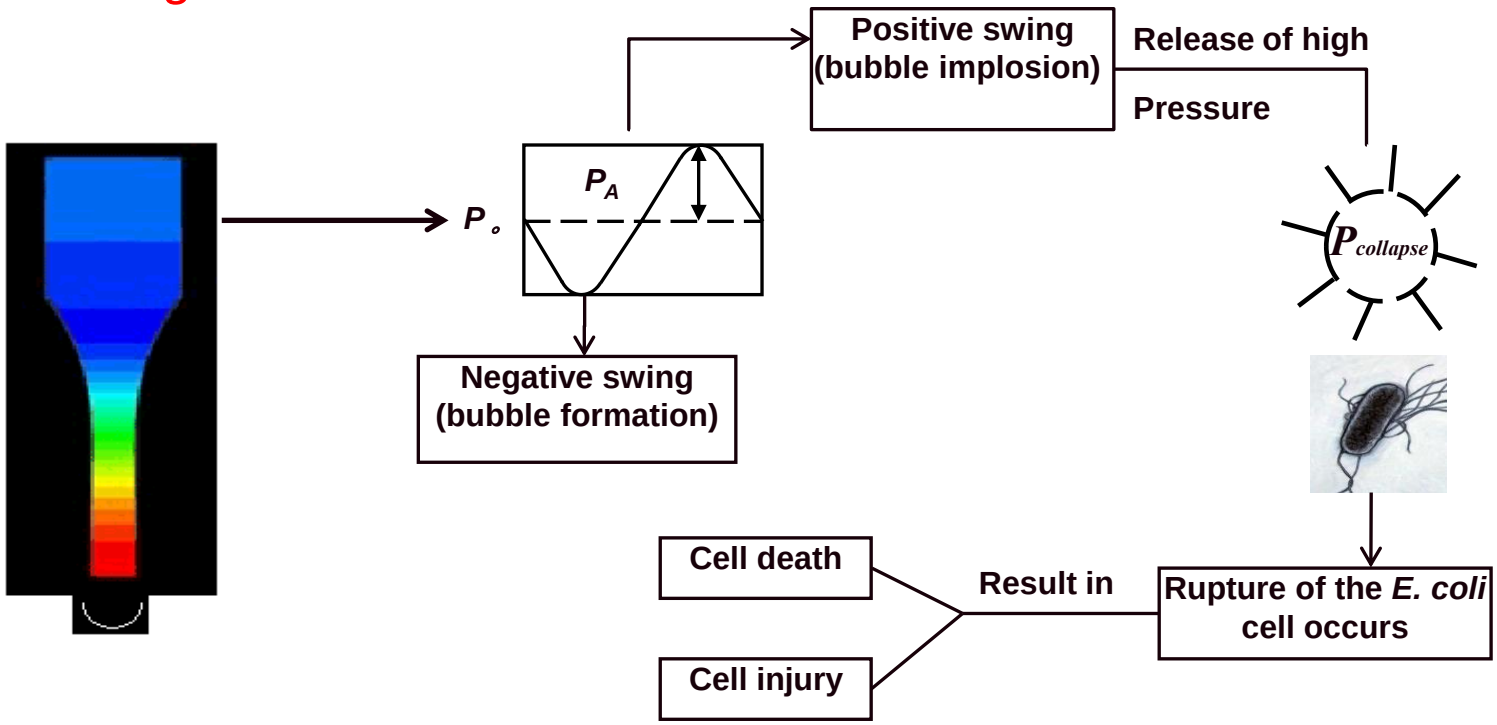


2. Aim of the research

This research aims to use ultrasound technology as a free chemical pre-treatment to reduce the formation of bio-fouling in membrane systems.

3. Disruption of *E. coli* cell under the effect of ultrasound (theoretical study)

3.1. Schematic diagram



3.2. Shock wave map – FE Simulation at USQ

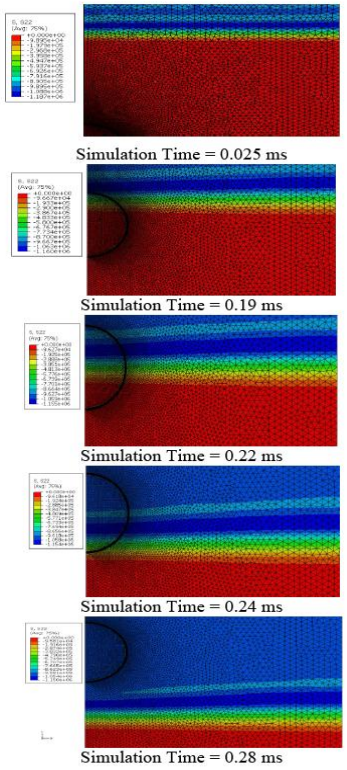


Fig. 4 Images of the radial stress wave propagation through the water, membrane and the cytoplasm using material properties of E = 112 MPa, ν = 0.4995 and density 1000 kg/m^3 throughout the entire domain (part 1, 2 and 3).

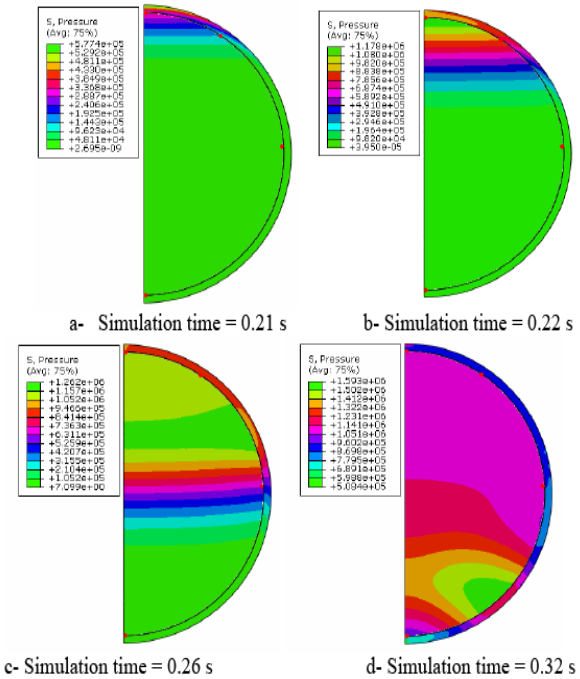
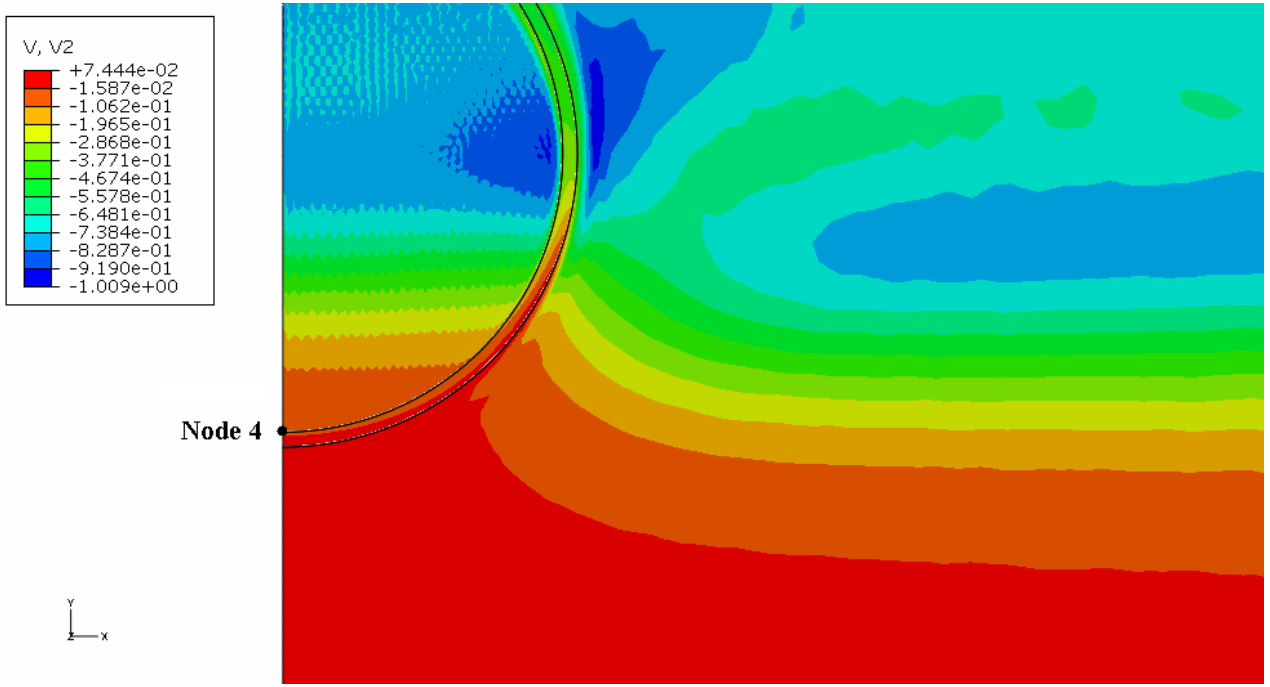


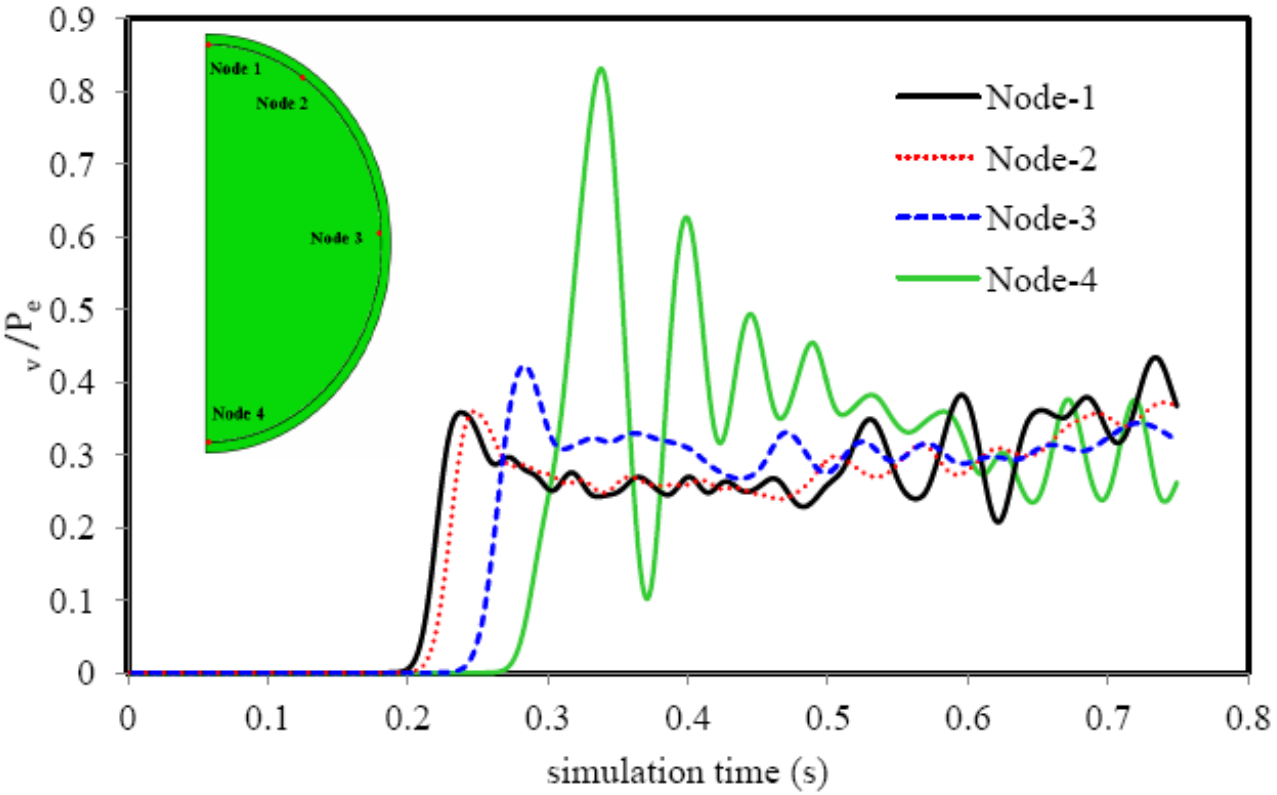
Fig. 9 Maps of pressure wave travelling through the cell at different simulation times of a- 0.21 s, b- 0.22 s, c- 0.26 s and d- 0.32 s.

3.3. Shock wave map – FE Simulation at USQ



Wave speed (m/s) through the water, membrane and the cytoplasm.

3.4. Von Mises concentration



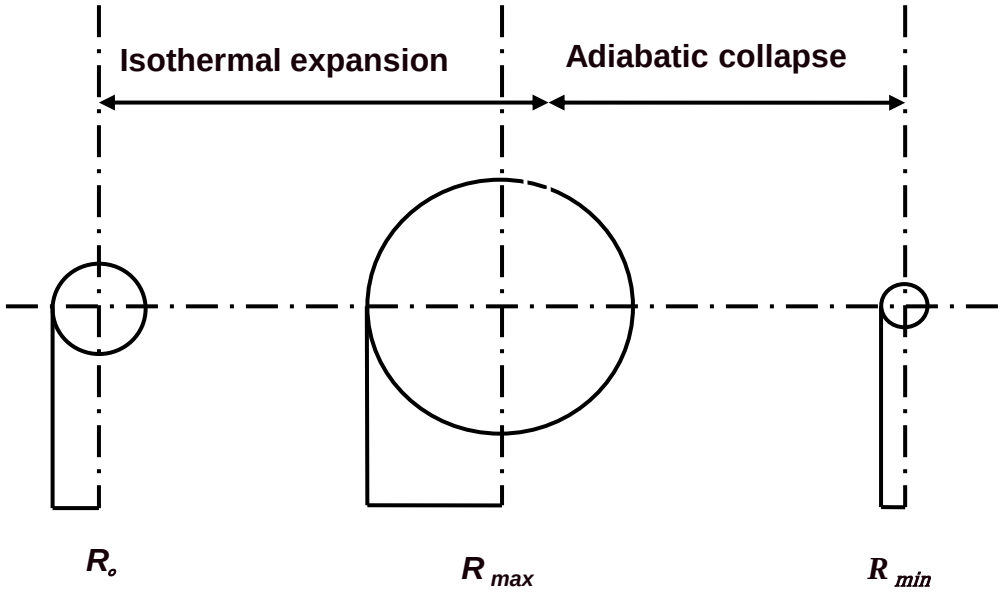
3.5. Factors affecting on the pressure released from bubble implosion (Pcollapse)

$$R\frac{d^2R}{dt^2} + \frac{3}{2}\left(\frac{dR}{dt}\right)^2 = \frac{1}{\rho_L}\left(P_B - \frac{4\mu_L}{R}\frac{dR}{dt} - \frac{2\sigma}{R} - P_\infty\right) \quad \text{..... 1}$$

$$P_{collapse} = 2P_{v\,sat}\left(\frac{R_{max}}{R_{min}}\right)^{3\gamma} \quad \text{..... 2}$$

A MATLAB routine was developed to evaluate the effect of the process parameters of ultrasound treatments such as Ultrasonic intensity, Ultrasonic frequency, Temperature of the treated water and Pressure of the treated water on $P_{collapse}$ through their effect on R_{max} and R_{min} (equation 2).

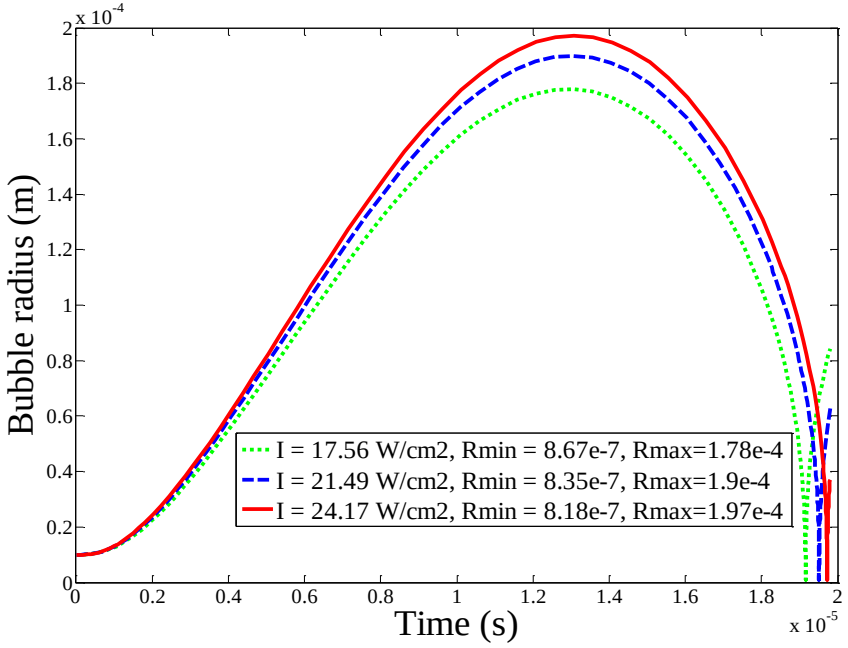
3.5. Factors affecting on the pressure released from bubble implosion (Pcollapse)



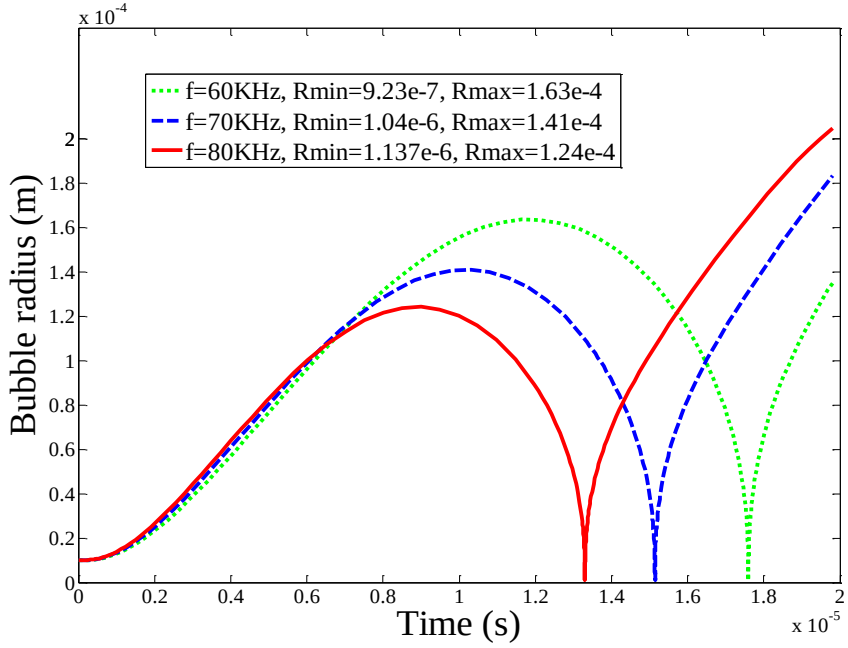
Schematic illustrates the life span of a transient bubble

3.5. Factors affecting on the pressure released from bubble implosion (Pcollapse)

Ultrasonic intensity

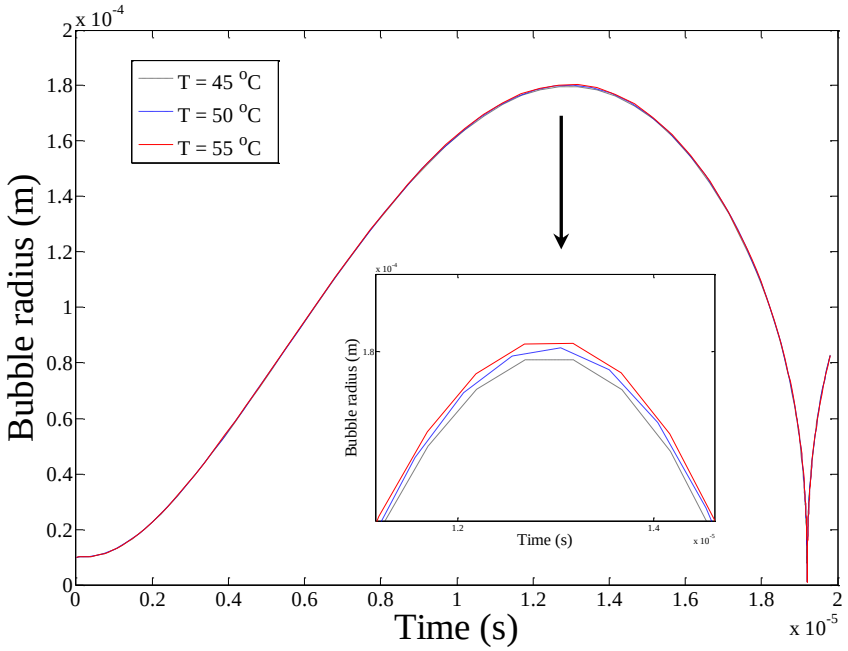


Ultrasonic frequency

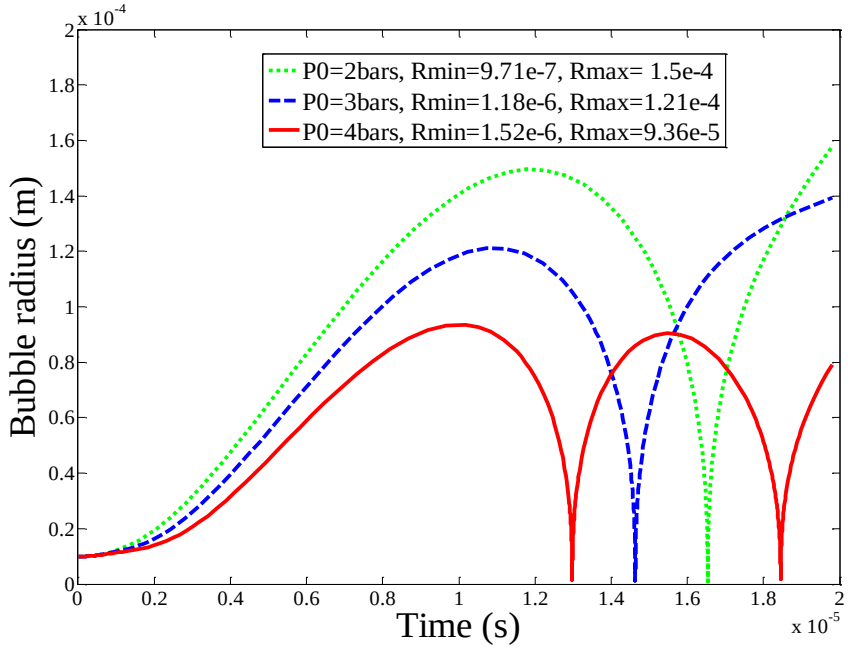


3.5. Factors affecting on the pressure released from bubble implosion (Pcollapse)

Temperature



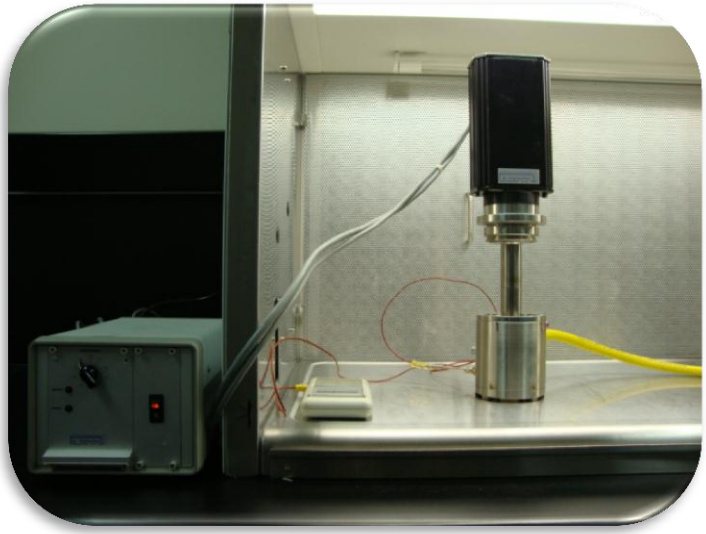
Pressure



4. Experimental apparatuses and test procedure

4.1. Apparatus description

RO stirred cell and RO membrane were obtained from Sterlitech Corporation USA.

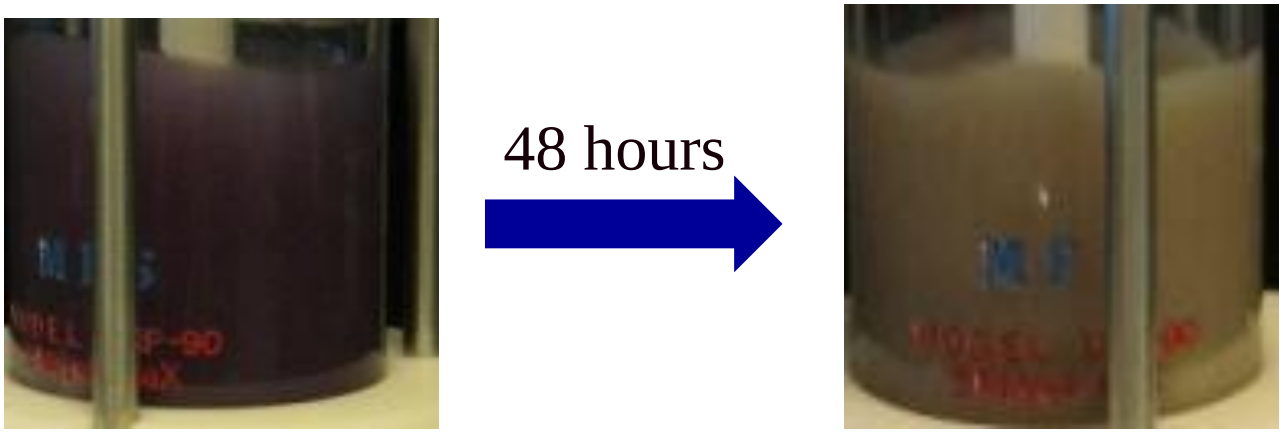


A commercial ultrasonic horn device (HielscherUIP500) with a 22 mm diameter horn tip (sonotrode, BS20d22 titanium) and a 60 kHz frequency was used to perform the experiments of sonication, thermosonication and manosonication.

4.2. E. coli preparation

E. coli was selected to be the sample microorganism in this work owing to its widespread use as an indicator for the microbial contamination in most of the water resources (Szewzyk et al., 2000) and its ability to adhere and subsequently develop biofilm on RO membrane (Hori and Matsumoto, 2010, Danese et al., 2000).

E. coli ATCC 25922 stock culture (cooked meat medium) and MacCONKEY broth were provided from Faculty of Science/ University of Southern Queensland)



4.3. Viable cell count and estimation of cell injury

Viable cell count technique was used to measure the concentration of E. coli at different stages of the treatment .

Triplication for the plates of the entire dilution series was applied to improve the accuracy of the viable cell count.

To measure the concentration of the injured cells in the treated suspension , samples of the treated suspension were plated on Tryptone Soya Agar (TSA) as a non-selective medium and MacCONKEY Agar as a selective medium.

SUNTEX colony counter model

4.4. Staining and epiflourescence microscopy techniques

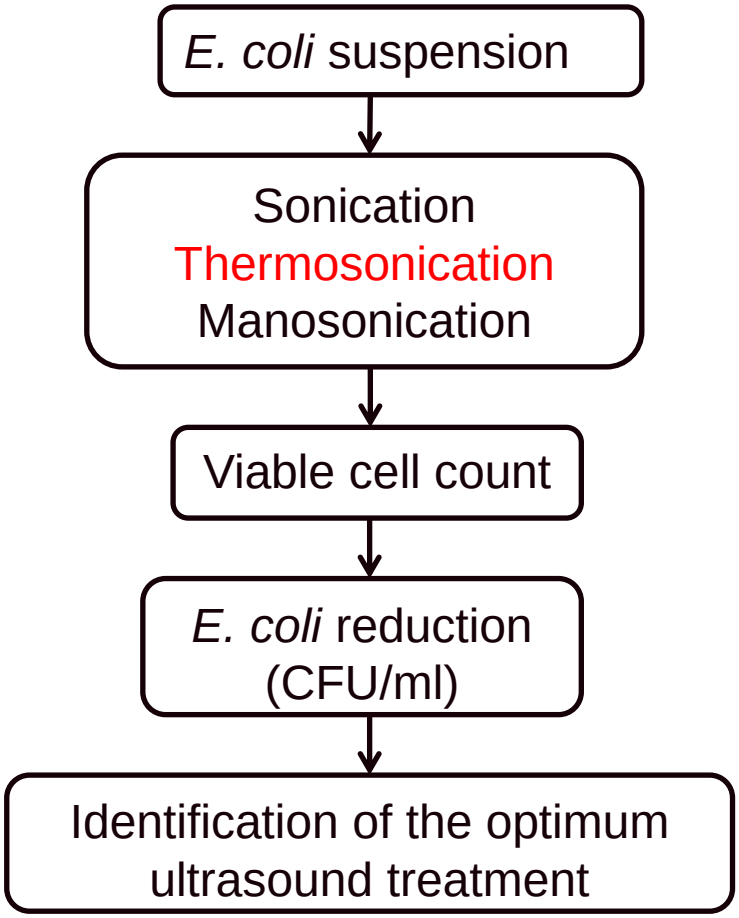
LIVE/DEAD BacLight^{TM} Bacterial Viability Kit for microscopy and quantitative assays (Invitrogen Molecular Probes, Victoria-Australia) was used to stain the adhered *E. coli* on RO membrane.

The stained cells were visualized using epiflourescence microscope (Nikon, Eclipse, E600) .

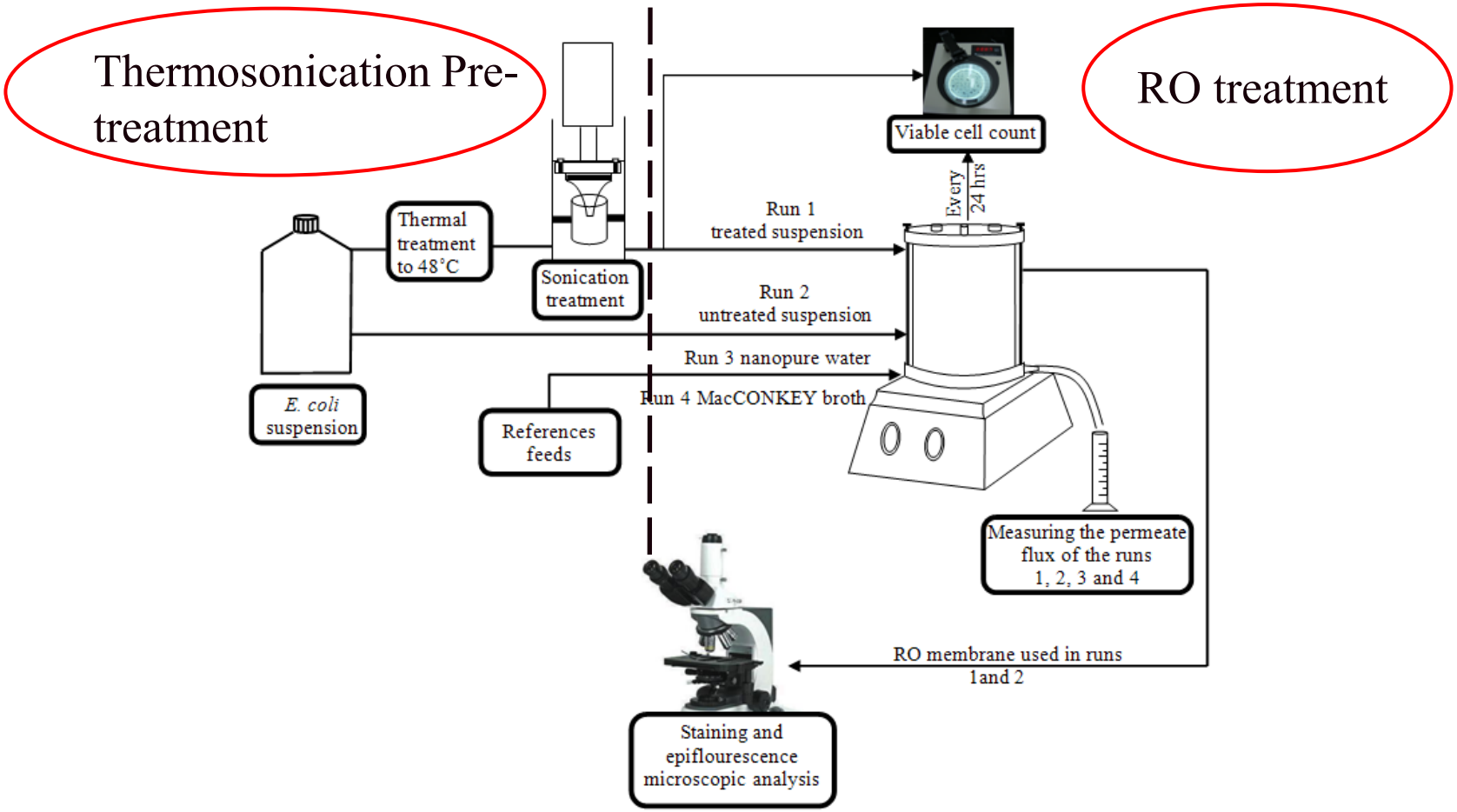
MicroPublisher 5.0 RTV camera that was equipped with fluorescence microscope and attached to a computer was used to take photomicrographs of the developed bio-film on RO membrane.

The captured microphotographs of the biofilm were optimized using Analysis FIVE software.

4.5. Procedure of ultrasound treatments

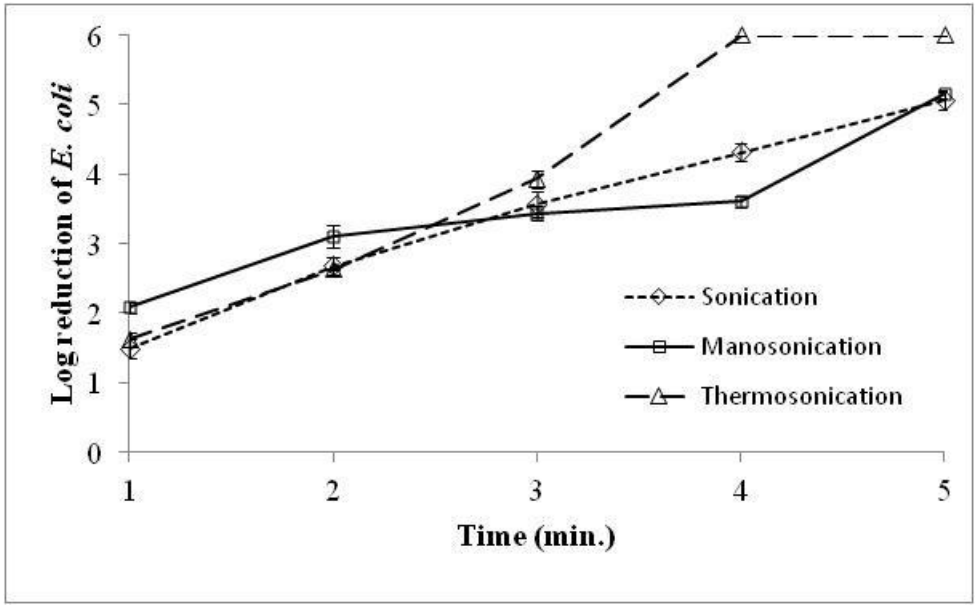


4.6. Procedure of control experiment



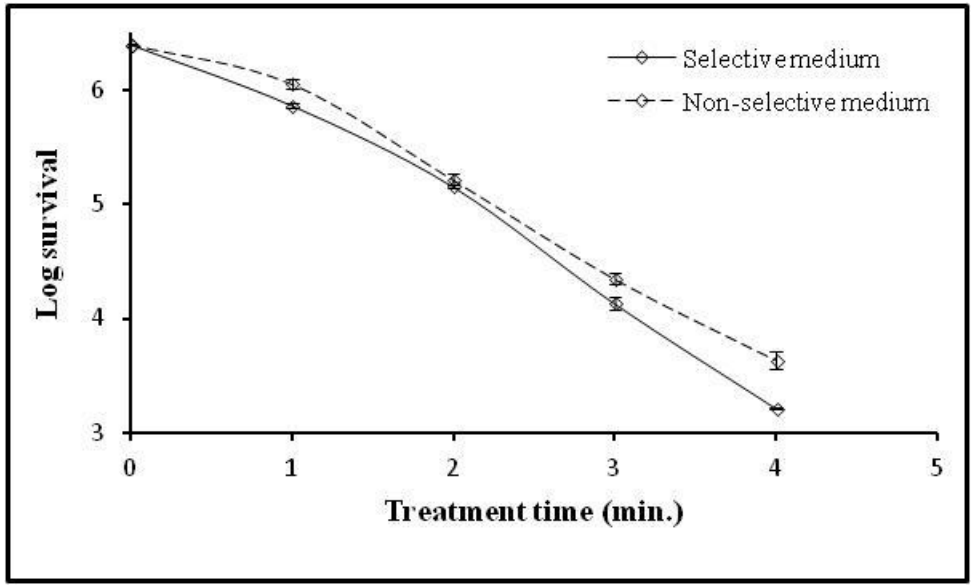
5. Results and discussion

5.1. Optimum ultrasound treatment



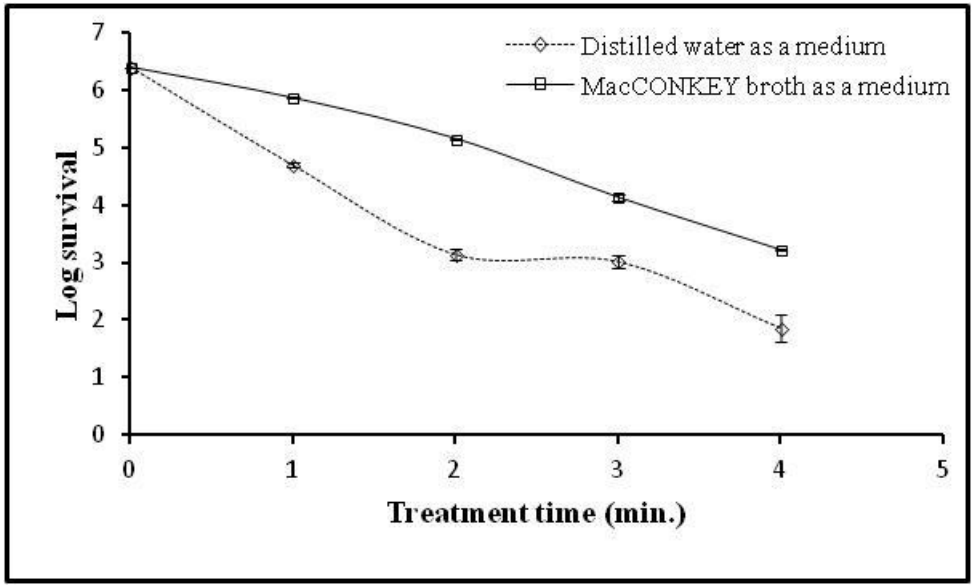
Comparison between sonication, manosonication and thermosonication

5.2. detection of cell injury cell death under the effect of thermosonication treatment



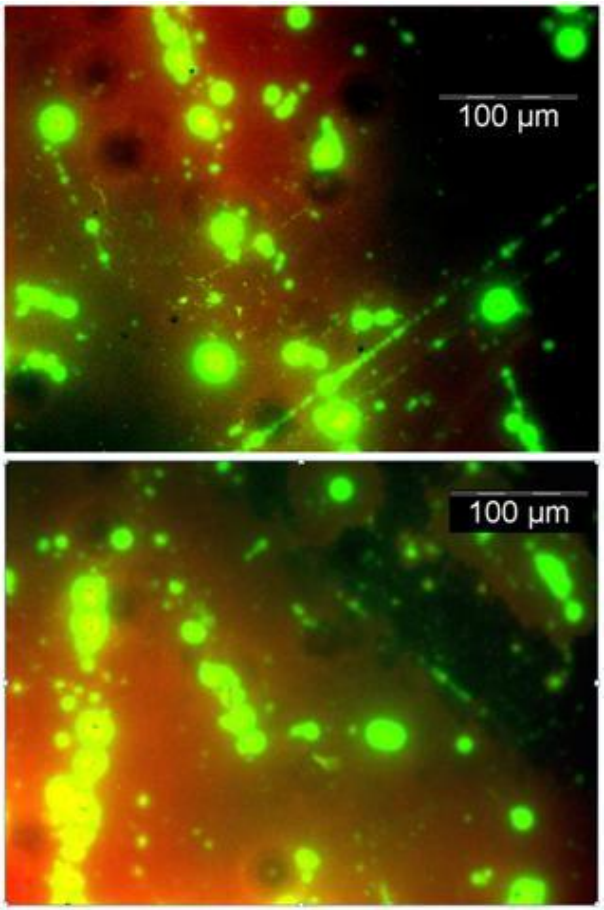
Cell injury in thermosonication treatment

5.3. Monitoring the reproducibility of the treated E. coli as opposed to the untreated E. coli .

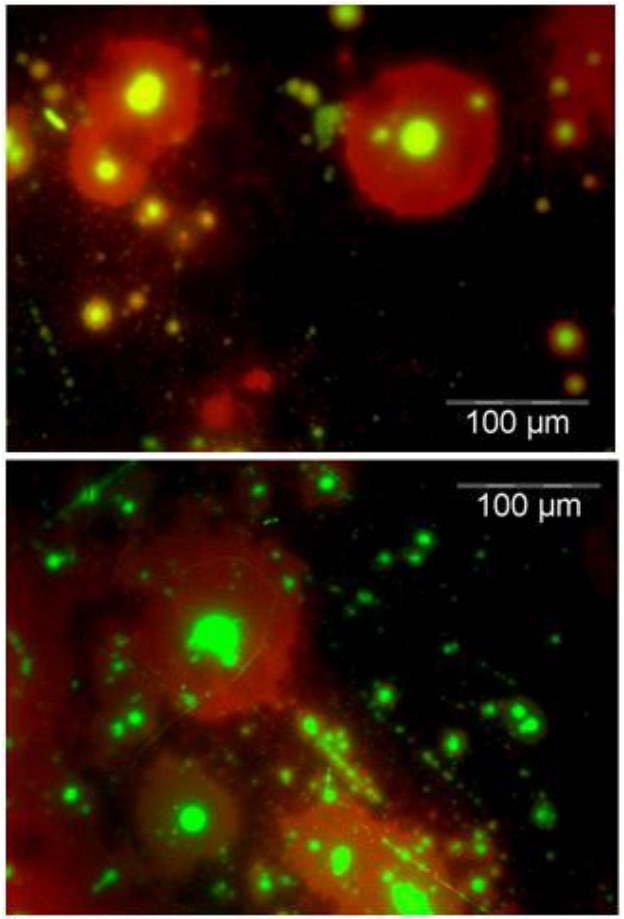


Reproduction of *E. coli* during RO treatment

5.4. Visualisation the developed bio-film on RO membrane

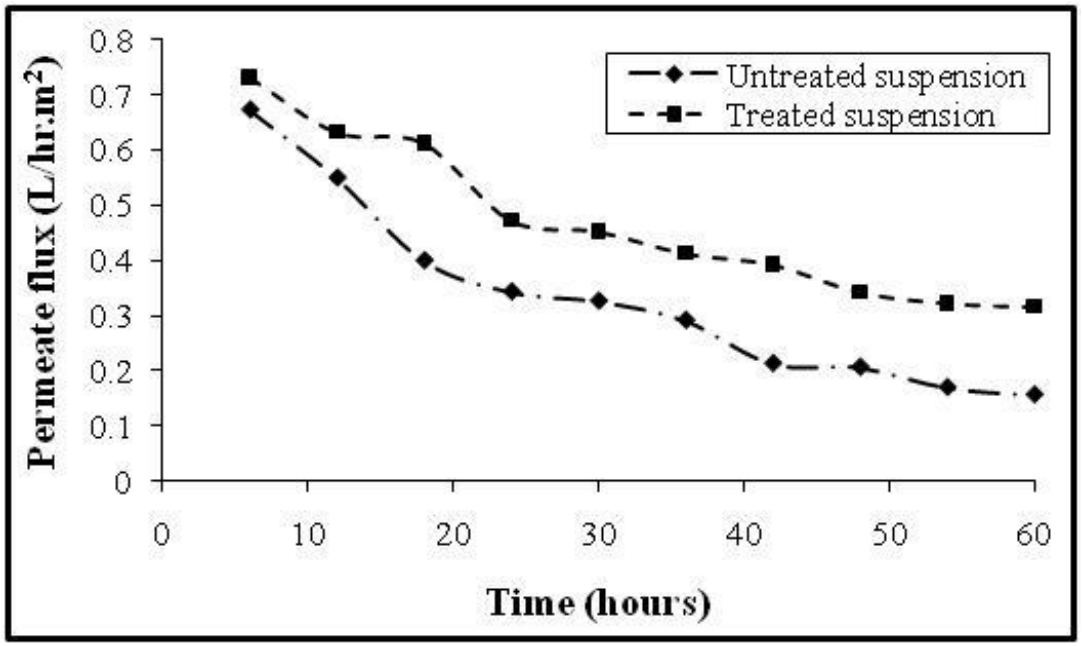


Untreated suspension



Treated suspension

5.5. measuring permeate flux of untreated and treated suspensions



Permeate flux of the treated suspension as compared to the untreated suspension

5. Conclusion

It can be concluded that ultrasound is an effective free chemical technique to reduce the formation of bio-fouling in membrane systems. The potential of ultrasound in reducing bio-fouling lies in its destructive effect on

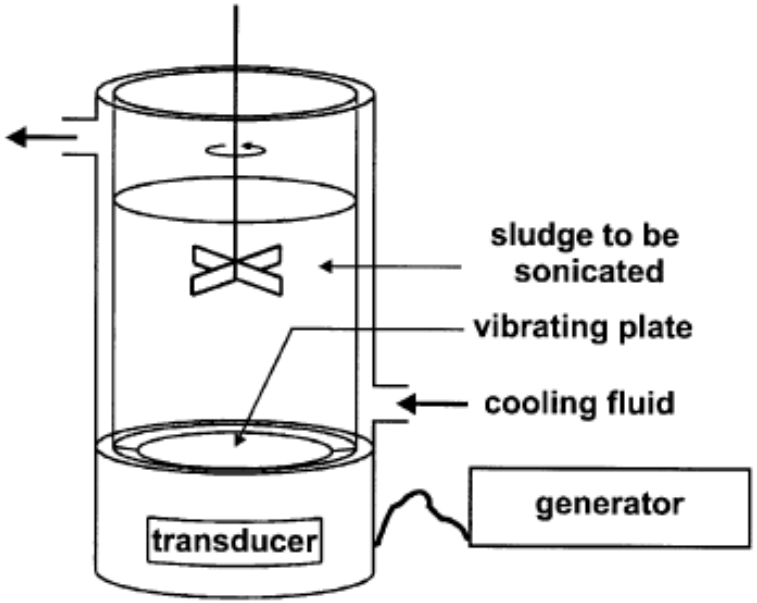
- the structure of microorganisms' cells, and
- the proliferation of microorganisms in the treated water.

"Water is the oil of the 21st century"

Andrew Liveris

Improving an aerobic digestion for waste activated sludge – Biogas Production in Churchill Abattoir, Ipswich, Queensland.

Lagoon of activated sludge



Implementing ultrasound in improving the production of biogas from the activated sludge (Tiehm et al., 2001).

Thank you

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By Saddam H. Al-lwayzy & Talal Yusaf