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PST024 - ULTRASONIC POWERFLOW: A CAVITATION-DRIVEN FLOW SYSTEM FOR CELL DISRUPTION

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ABSTRACT

Ultrasound disinfection represents a significant technological advancement with potential applications across multiple domains, such as water and wastewater treatment, food processing, and industrial settings. Practically, the ultrasonic treatment was performed to minimize negative environmental impacts by producing zero by-products without the addition of any additives. Thus, this study aims to explore safer and more efficient disinfection methods that address this issue, focusing on the use of Ultrasonic PowerFlow cavitation-driven. The advanced system utilizes frequency ultrasound waves to generate microbubbles that collapse under pressure, producing high shear forces that effectively inactivate pathogenic cells. Flow cell ultrasound was fabricated as a continuous flow process and adjusted to a loop reactor operating at 30 kHz, with a variation of power increments to the system (14, 35, 50, 64 and 92 %). The evaluation performance of flow cell ultrasound based on the disruption of *Escherichia coli* wild-type cells as a model organism and kinetic disinfection analysis. By identifying optimal conditions: 60 minutes of sonication, 35% power increments, Inoculum 10^8 Colony Forming Unit (CFU)/ml and a flow rate of 55 ml/min. The present investigation adhered to a first-order kinetics model and achieved a higher inactivation rate constant of 0.0286 min^{-1} (R^2 = 0.992) for the cells as a function of time in the kinetic process. This study demonstrates that the flow cell ultrasonic reactor is a highly effective and energy-efficient method for disinfection, offering a green alternative to traditional chemical methods. Indeed, the present findings support the goals of the Green Technology Master Plan Malaysia 2017–2030 by promoting sustainable and environmentally friendly solutions in the water and wastewater technology sectors.

Keywords – Flow cell ultrasound, bacterial disruption, disinfection process, kinetic disinfection, ultrasound treatment

INTRODUCTION

Water disinfection and microbial control are crucial challenges in many industries, including water/wastewater treatment, food processing and industrial settings (Golfinopoulos et al., 2024). The conventional methods frequently depend on detrimental chemicals. The ultrasonic treatment was conducted to eliminate negative environmental impacts by generating zero by-products without the addition of any additives (Zou and

Tang, 2019). By examining the impact of irradiation throughout the treatment process, this study seeks to determine the impact of kinetic cell inactivation on the system. Thus, the **Ultrasonic PowerFlow** system addresses these limitations by leveraging the power of ultrasound cavitation to remove contaminants and inactivate cells without relying on chemical agents, making it a sustainable alternative.

OBJECTIVE

This invention develops an ultrasound-driven flow system that uses a cavitation mechanism to disinfect and inactivate the cells. It explores safer and more efficient disinfection methods and innovates to revolutionise water treatment by offering a greener, more efficient, and sustainable alternative to conventional disinfection approaches.

DESCRIPTION OF THE PROJECT

Ultrasound PowerFlow with a piezoelectric transducer was fabricated as a continuous flow process and adjusted to a continuous loop reactor (Figure 1). The specification of ultrasound operating at 30 kHz, a generator was used to provide electricity at various output levels with a variation of power increments to the system (14, 35, 50, 64 and 92 %), and 60 minutes of treatment duration. The operation of Ultrasound PowerFlow in a single input for the sample influent and a single exit for the treated sample was constructed at the unit.

The evaluation performance of **Ultrasonic PowerFlow** based on the kinetic degradation of *Escherichia coli* wild-type cells as a model organism against the irradiation effect. The kinetic inactivation impact is subjected to [In (living *E. coli* cells after irradiation)/ (initial number of *E. coli* cells)] over the treatment time. The inactivation rate constant (k, min^{-1}) values were interpreted from the cell inactivation of ultrasonic reactor performance, together with the correlation coefficients (R^2). The kinetic degradation of *E. coli* against irradiation effect followed first-order kinetics expression with a correlation value of 0.0286 min^{-1} and R^2 = 0.992 for the linear fitting line.

The mechanism employed in cell damage inactivation via cavitation effect corresponds to numerous processes associated with energy dissipation in the irradiated region. The technical operation of an ultrasonic cylindrical curvature reactor produces numerous processes, including creating cavitation bubbles (Lei et al. 2023). These bubbles collapse, leading to a mechanism cavitation effect (Song et al. 2024), and finally, they employed the lethal impact on the model organism.

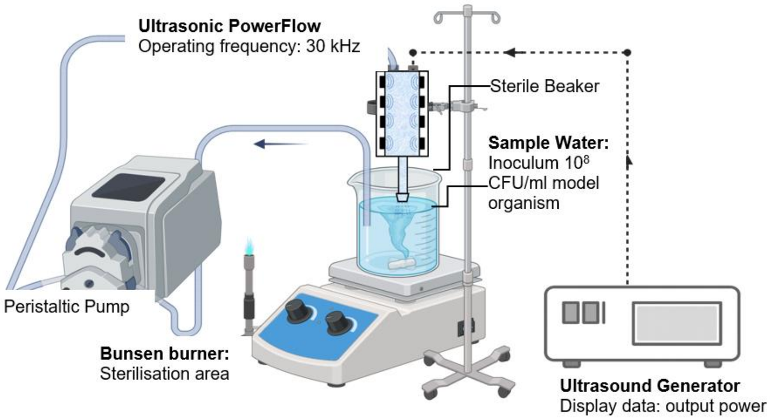

Figure 1: Schematic Diagram of Unltrasonic PowerFlow Experimental Setup

NOVELTY

The mechanical inactivation of pathogenic bacterial cells by the disinfection process employing the cavitation mechanism. The geometrical transducer curvatures of the flow cell ultrasound reactor, as equipped with multiple transducers, produce greater effects within the acoustic cavitation zone. Therefore, it demonstrates enhanced efficiency relative to the preceding ultrasound reactor.

CONCLUSION

This study demonstrates that the flow cell ultrasonic reactor is a highly effective and energy-efficient method for disinfection, offering a green alternative to traditional chemical methods. This study implemented a first-order kinetics model and discovered that the cells had a higher deactivation rate constant of 0.0286 min^{-1} and an R^2 value of 0.992. The present results contribute to the Green Technology Master Plan Malaysia 2017-2030 by encouraging sustainable and environmentally friendly solutions in the water and wastewater technology sectors.

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