UNIVERSITI TEKNOLOGI MARA

WILD-TYPE *Escherichia coli* DISINFECTION BY FLOW CELL ULTRASOUND: MECHANISMS AND OPTIMISATION THROUGH NEURAL NETWORKS

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ABSTRACT

The goal of this thesis is to investigate the use of the flow cell ultrasonic reactor as a disinfection treatment for the disruption of wild-type cells of *E. coli* as model organisms and to recommend that the custom ultrasonic reactor be adaptable to real environmental disinfectants as there is growing global concern about green disinfection technology. There are several challenges associated with ultrasound treatment; the requirement for high energy consumption continues to be a significant constraint on ultrasonic application in water and wastewater treatment systems, as well as industrial applications. Additionally, the lower cavitation region and irradiating surface of the ultrasonic reactor reduce treatment performance. Besides that, there is insufficient information about the cell's mechanical impacts, as evidenced by qualitative and quantitative methods using depth microscopy and particle size analysis of ultrasonic treatment on *E. coli* wild-type cells disruption. A comprehensive investigation using a combination of microscopy techniques, including gram-staining analysis, Environmental Scanning Electron Microscopy and High-Resolution Transmission Electron Microscopy, demonstrated and concluded that flow cell ultrasound treatment had a significant effect on cell disruption. Furthermore, with the design of frequency transducers at 30 kHz, this improves the performance of the ultrasonic reactor and has a greater impact on the disinfection process. Moreover, the interconnections between operational parameters in flow cell ultrasound treatment have an impact on treatment performance. The optimal operation of an unsubmerged reactor is associated with the geometry of the reactor structural design. The curve estimation confirms that the behaviour of cells inactivated to the treatment duration in multilayer perceptron yielded a regression line with a determination coefficient greater than 89%, together with a lower intercept as model bias fit a data set to the linear regression model behaviour. RMSE has given the average error between the experimental data and the predicted value. In addition, the residuals-predicted on the experimental model were not clear patterns and were considered a good fit model. Hence, this presents greater confidence in the linear regression model behaviour between predicted and observed data. The 60-minute treatment duration and cell inactivation in linear regression behaviour ($p < 0.0001$) and further extended treatment duration until 110 minutes led to the change in the behaviour of quadratic models ($R^2 = 0.811$). The increase in treatment duration with of more than 60 minutes appeared to reduce the death cell rate. The trend removal reduced the rapid disruption and generated a tailing phenomenon. It is important to note that the higher performance of the flow cell ultrasonic reactor on inactivation effect was referred to the sonication parameters. This resulted in the interaction between microbubbles and membrane cells with mechanical and chemical damage inactivation effects. Thus, the mechanical inactivation effects such as liquid microjets, shockwaves, acoustic streaming, and combinations of chemical cytotoxic effects through reactive oxygen species act as a pillar in the cell's inactivation effect. Meanwhile, oxidative radical-induced lipid oxidation was the primary target for membrane oxidation, and it was noted that oxidation was advantageous in a membrane because oxygen was more concentrated in the hydrophobic environment of lipid bilayers than in solution. Further, microscopy images and particle size analysis showed flow cell ultrasound treatment caused lethal effects due to mechanical damage to the cells and a proven tailing phenomenon during the treatment. Therefore, the flow cell ultrasonic reactor was an efficient sustainable disinfection technology towards increasing energy efficiency.

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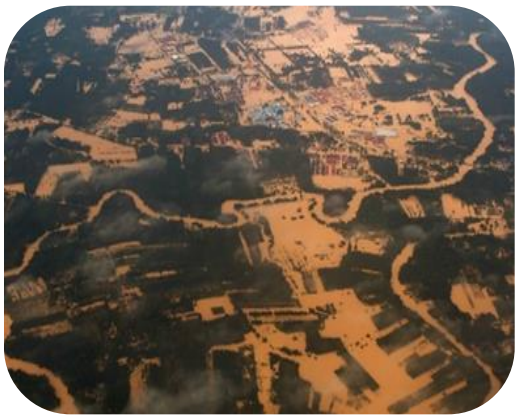
CHAPTER ONE

INTRODUCTION

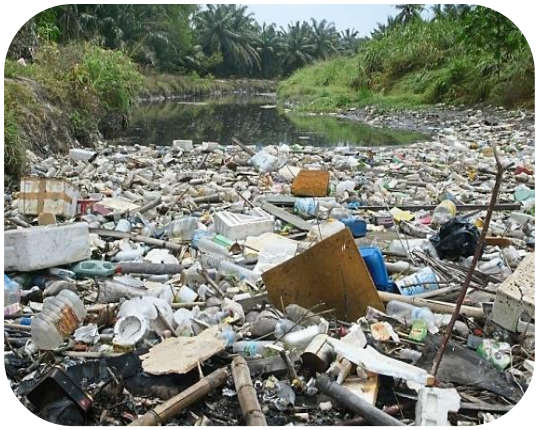
1.1 Background of the Study

Water is a necessity in our daily life. It is now universally agreed that providing the community with safe water acts as a preventive measure to prevent outbursts of waterborne plague. In addition, the demand for clean water supply has risen in the new decade of the twenty-twenties. Due to increased contamination as a result of industrialisation and urbanisation activities, conventional drinking water treatment systems encountered difficulties (Figure 1.1).

Children playing in a water pool on a parched padi field in Kampung Sangkir, Kota Belud, Sabah, Malaysia on March 3, 2019



Aerial view depicts houses and plantations in floodwaters in Pengkalan Chepa, Kelantan, Malaysia on December 28, 2014



Non point-source discharge, among them is river pollution loads (Nadarajan, 2019). 2017 Malaysian Environmental Quality Report: (i) Since 2015, percentage polluted rivers increased, (ii) BOD concentration, none of the monitored rivers has been clean categorized.

Figure 1.1 Contaminating Sources of Surface Water