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Ultrasonic Technology Effectiveness in Total Coliforms Disinfection of Water

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Abstract: The effect of ultrasonic upon the destruction of total coliforms has been studied in this research. Also, the impact of power intensity and ultrasonic frequency on the germicidal effectiveness of sonification has been explored. The results obtained from the work carried out have shown that ultrasonic can be used effectively for water disinfection and increase in percent kill for coliforms may occur with increase in contact time to ultrasonic in the 42 kHz. These results suggest that ultrasonic in this frequency is capable to some degree in inactivating total coliforms in water.

Key words: Ultrasonic, power intensity, total coliforms, germicidal effectiveness, water disinfection, sonification

INTRODUCTION

Water is an essential component in the make-up of this planet and plays an essential role in supporting all life. When contaminated, however, it can transmit a wide variety of diseases and illnesses to man. Therefore it is of the utmost importance to produce through treatment processes a final potable water which is microbiologically safe[1,2].

Whilst treatment processes are able to reduce the number of micro-organisms in water they can never ensure complete removal and so final disinfection is perhaps the most important stage of water treatment, being the final safeguard against water-borne microbial disease. Although chlorine disinfection has proved to be successful in eradicating water-borne diseases, there are problems associated with this method. Therefore, alternative disinfection techniques are being evaluated and the benefits of the use of ultrasonic in the water industry are now of considerable interest[3,4].

Today that situation has changed, ultrasonic technology is more common place, costs have been reduced and applications are more economic. Power ultrasonic can now be considered to be a viable alternative to conventional bactericidal techniques[5,6].

Ultrasonic is able to inactivate bacteria and deagglome rate bacterial clusters or flocs through a number of physical, mechanical and chemical effects arising from acoustic cavitation On collapse, cavitation bubbles produce enough energy to mechanically weaken or disrupt bacteria or biological cells via a number of processes:

- Forces due to surface resonance of the bacterial cell are induced by cavitation. Pressures and pressure gradients resulting from the collapse of gas bubbles which enter the bacterial solution on or near the bacterial cell wall. Bacterial cell damage results from mechanical fatigue, over a period of time, which depends on frequency[7].
- Shear forces induced by micro streaming occurs within bacterial cells[8].
- Chemical attack due to the formation of radicals (H. and OH.) during cavitation in the aqueous medium. These radicals attack the chemical structure of the bacterial cell wall and weaken the cell wall to the point of disintegration[8].
- Amongst the final products of this sonochemical degradation of water is hydrogen peroxide, which is a strong bactericide[9].

Sonication alone can provide powerful disinfection. However, to achieve 100% kill rates using only ultrasonic it is necessary to use high ultrasonic intensities. This makes the technique expensive to use for general large-scale decontamination but nevertheless there is a drive towards the use of ultrasonic in decontamination as an adjunct to a bactericide and in conjunction with other techniques[10,11].

In this study the use of ultrasonic in the disinfection process of potable water has been described.

The major objective was determining ultrasonic effectiveness in treatment of biological agents of water (Tehran University of Medical Sciences, 25 Aug. 2004).

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MATERIALS AND METHODS

The use of ultrasonic: Ultrasonic was applied to samples using a Laboratory cleaning bath with the following characteristics:

Model:	1510E-DTH		
Input:	220-230 V	155 W	0.7A
Output:	70 W	42 kHz	

Bransonic Ultrasonic Cleaner

A series of experiments involved sonicating of total coliforms and observing the effects of ultrasonic upon its growth. Before sonication, the concentration of total coliforms in water was adjusted to as high as 1600 (MPN/ 100 mL). This sample was added to the batch reactor in which sonication could be performed. For micro-organisms destruction investigation in ultrasonic bath, small volumes (300, 600 and 800 mL) of water have been used. All components in laboratory placed in an autoclave for disinfection before each test. The effect of sonicating different volumes of water was measured for the same time intervals. The samples were sonicated in periods of 1,5, 15, 20, 30, 40, 50, 60, 70, 80 and 90 min. For each trial namely, each sample was exposed to all of the durations. The number of trials per the mentioned exposure levels was variable. Finally, required samples for analyses were taken after 1, 5, 15, 20 min and determination was performed according to the standard total coliform fermentation technique (9221 B)[12].

Microbiological experiment: The coliform group consists of several genera of bacteria belonging to the family Entrobacteriaceae. The standard test for the coliform group carried out by the multiple-tube fermentation technique in this research. On this basis, results of the examination of replicate tube and dilutions are reported in terms of the Most Probable Number (MPN) of organisms present. The precision of each test depends on the number of tubes used. For analyzing drinking water it is recommended to use the fermentation technique with 10 replicate tubes each containing 10 mL, 5 replicate tubes each containing 20 mL, or a single bottle containing a 100 mL sample portion.

All the analyses (presumptive and confirmed test) were performed according to the procedures outlined in standard methods[12].

Statistical methods: The effects of ultrasonic irradiation on viability of total coliforms were analysed statistically by using ANOVA. The dependent variable was relative percent kill with ultrasonic and independent variables were intensity and time.

RESULTS AND DISCUSSION

In this study, the major objective was to study the effectiveness of ultrasonic in treatment of biological agents. This is the first report in Iran.

Disinfection by ultrasonic is accomplished by one of three routes: The destruction of bacterial cells by ultrasonic lysis. The removal of excess chlorine from water after chlorination, by ultrasonic degassing, thus allowing higher dose used during the disinfection stage. The deaggregation of clumps of bacteria or other material trapping such bacteria to expose the masked cells to disinfection[13].

Biocidal effect of ultrasonic: The results show that increasing the sonication time has a significant effect on bacterial kill. Also, there is no significant kill of total coliforms in less than 20 min contact time to 42 kHz but considerable levels of inactivation can be expected at higher periods.

The bio-effects of sonication at different volumes: When ultrasonic bath is used to sonicate smaller volumes of bacteria at low frequency, there is a resultant in the intensity of ultrasonic entering the system. The highest and lowest bacteria reduction after sonication for 300 mL and 600 mL volumes were 99.94% and zero. Also, for 800 mL volumes were 99.63% and zero, respectively. Furthermore, this study showed removal efficiency in 90 min was highest. On the other hand, sonication of smaller volumes produced a more rapid kill. Also, up to 99.84% reduction in bacteria concentration was achieved with the majority of these reduction found to occur in the 90 min (Table 1).

Table 1 presents the exposure time versus the percent kill. From this present studies, the effects of ultrasonic upon the destruction of micro-organisms, it can be seen that ultrasonic is suitable for water disinfection and can achieve the following[14].

Table 1: The effects of sonication time on killing percentage of total coliforms in the different volumes

	Sample volume (mL)			
Sonication time (min)	300	600	800	Percent kill
1	0.00	0.00	0.00	0.00
5	43.75	43.75	43.75	43.75
15	81.25	81.25	73.33	78.61
20	84.37	82.50	81.25	82.71
30	91.25	83.12	82.50	85.62
40	98.63	97.94	96.88	97.82
50	99.50	99.12	98.37	99.00
60	99.62	99.31	98.93	99.29
70	99.75	99.56	99.18	99.51
80	99.88	99.75	99.25	99.63
90	99.94	99.94	99.63	99.84

Table 2: ANOVA for removal efficiency of total coliforms in the different volumes

	Efficiency (%)				
Samples volume (mL)	Mean (%)	SD (%)	p-value		
300	81.16	31.8	df	F	p
600	81.13	31.7	2	0.016	0.984
800	78.98	31.5			
Total	80.39	30.7			

Remove chlorine from water efficiently. Ultrasonic reduces the amount of chlorine required for disinfection. Sonication leads to the formation of dead bacterial cells or selectively destroying weak bacteria.

Analyses showing that there was no significant difference between mean of the different volumes (p=0.984) (Table 2).

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