Ultrasound Assisted Scouring of Raw Wool

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Abstract

In the present paper, the role of ultrasound is studied in the scouring process and the results are evaluated in terms of grease, other fatty matter and suint removal efficiency by Soxhlet extraction method. Three types of raw wool fibres viz., fine, medium and coarser grade wool were scoured with and without ultrasound. The results indicate that if all the parameters of scouring recipe are kept same, the fat and suint removal efficiency gets doubled in presence of ultrasound. It was also found that ultrasonic scouring can be done at lower temperature and chemical concentration. The feasibility of using ultrasonic technique at industrial level was studied using immersible type of ultrasonic tube resonators which can either be fixed inside the scouring bowls or suspended longitudinally.

Keywords: ultrasound, raw wool, scouring, tube resonator

1. Introduction

Wool is a natural fibre which in raw form comprises nearly 30% of its weight by contaminants. These contaminants consist of 5-25% grease, 2-15% suint and 5-20% dirt and vegetable matter. These impurities need to be removed before any further processing. This is done by scouring the wool. The conventional methods of wool scouring utilize high amount of chemicals, detergent, alkali etc which create some serious problems; both, for the environment and the industry while effluent treatment and disposal [1].

Ultrasound has been successfully used to accelerate various chemical processes and is industrially used for precision cleaning of automotive parts, medical tools such as syringes etc [2]. In textiles, ultrasound has successfully demonstrated its usefulness in processes such as bleaching, dyeing, washing, etc for saving in time and temperature. Experiments carried out by various researchers have revealed that, desizing of cotton and nylon fabrics under ultrasonic treatment results in complete removal of oils used in the size recipe while the treatment without ultrasound shows residual oil stains [3-7]. The effect of ultrasound in the wool scouring process however has not been thoroughly investigated so far and hence, this issue is addressed in the present study.

1.1 Ultrasonic technology

Ultrasound is the sound with frequencies above 18 KHz which is above the limits of human audibility. Ultrasonic energy offers many potential advantages such as energy savings, and reduced processing times, environmental improvements, process enhancement and lower overall processing costs [8, 9]. Ultrasound appears to be a very promising alternative technique to provide a far more efficient stirring or mixing mechanism for the immediate border layer of liquid at fibre surface [10.11].Generally, sonication of liquids causes two primary effects, namely; cavitation and heating. As the ultrasound passes through a liquid, it produces compression and rarefaction regions in it. During the rarefaction phase, the liquid is literally torn apart, creating millions of microscopic cavity bubbles in it. When these bubbles collapse at the surface of the solid substrate (e.g. textile fibre), they generate powerful shock waves which remove the contaminants adhered to the substrate [12, 13, 14].

Cavitations are generated in the order of microseconds. It is estimated that the pressure is about 35-70 K Pascal and the transient localized temperatures are about 5000°C with the velocity of micro streaming around 400 Km/hr. These conditions tremendously improve the cleaning process [15, 18].
The present study was carried out at 35 kHz frequency.

2. Materials & Methods

2.1 Materials

2.1.1 Raw material

The scouring experiments were carried out on three types of raw wool fibres

- Fine merino wool of average diameter **20 micron**
- Medium grade merino wool of **24.5 micron**
- Slightly coarser grade wool of **30 micron**

2.1.2. Chemicals

Sodium carbonate, Lissapol N (non-ionic detergent), Dichloromethane of L.R. Grade

2.2 Methods

2.2.1. IWTO- 47-00 Test Method

The diameter of wool fibres used for the experiment were tested by IWTO- 47-00 Test Method (Method for measurement of the mean and distribution of fibre diameter of wool using an optical fibre diameter analyzer (OFDA))

2.2.2 IWTO -10-02 Test Method

The grease content of wool was tested by IWTO -10-02 Test Method (Method for the determination of the dichloromethane soluble matter in combed wool and commercially scoured or carbonised wool)

3. Experimental

Ultrasonic experimental set-up

A lab scale Ultrasonic Cleaner experimental set-up modified and lined with additional transducers in the side walls (M/S Roop Telsonic Ultrasonix Ltd. India, TPC 280 Model) generating ultrasound at 35 kHz frequency had been employed. The ultrasonic output power was 1200 W. The capacity of the ultrasonic cleaner was 28 lit. In order to find out the influence of ultrasound on wool scouring process, the scouring experiments were carried out with and without ultrasonic irradiation.

3.1 Conventional scouring method

Conventionally, wool is scoured in aqueous condition using a hot composition of detergent and alkali like sodium carbonate [16, 17]. In industry, five scouring bowls are used to scour the raw wool. The scouring recipe used for this study is as shown in Table 1.

Table1. Conventional Aqueous Scouring Recipe

Parameter	Bowl No.1	Bowl No.2	Bowl No.3	Bowl No.4	Bowl No.5
Lissapol-N detergent (gm/lit)	NIL	0.8	0.4	NIL	NIL
Temperature (^oC)	60	55	50	40	40
Sodium Carbonate(gm/lit)	1.33	NIL	NIL	NIL	NIL
Time (min)	3	3	3	1.5	1.5

The material to liquor ratio (MLR) was 1:50 in all the bowls. The bowl no. 4 and 5 were rinsing bowls which contained plain water at 40^oC.

Table 1.1 Conventional Aqueous Scouring Recipe With Chemical Concentration Reduced To Half And Scouring Temperature Reduced To 45°C

Parameter	Bowl No.1	Bowl No.2	Bowl No.3	Bowl No.4	Bowl No.5
Lissapol- N detergent (gm/lit)	NIL	0.3	0.2	NIL	NIL
Sodium Carbonate(gm/lit)	0.5	NIL	NIL	NIL	NIL
Temperature (°C)	45	45	45	40	40
Time (min)	3	3	3	1.5	1.5

Table 1.2 Conventional Aqueous Scouring Recipe Without any chemical (i.e. without detergent and sodium carbonate)

Parameter	Bowl No.1	Bowl No.2	Bowl No.3	Bowl No.4	Bowl No.5
Lissapol- N detergent (gm/lit)	NIL	NIL	NIL	NIL	NIL
Sodium Carbonate(gm/lit)	NIL	NIL	NIL	NIL	NIL
Temperature (°C)	60	55	50	40	40
Time (min)	3	3	3	1.5	1.5

3.2 Ultrasonic scouring method

The influence of ultrasound in conventional scouring was studied by introducing ultrasonic irradiation in the second and third bowls of the conventional scouring method keeping all the other parameters and conditions same.

Table 2. Ultrasonic scouring recipe

Parameter	Bowl No.1	Bowl No.2	Bowl No.3	Bowl No.4	Bowl No.5
Lissapol- N detergent (gm/lit)	NIL	0.8	0.4	NIL	NIL
Sodium Carbonate(gm/lit)	1.33	NIL	NIL	NIL	NIL
Temperature (°C)	60	55	50	40	40
Time (min)	3	3	3	1.5	1.5
Ultrasound	No	Yes	Yes	No	No

Table 2.1 Ultrasonic Scouring Recipes with Chemical Concentration Reduced To Half and Scouring Temperature Reduced To 45^{o}C

Parameter	Bowl No.1	Bowl No.2	Bowl No.3	Bowl No.4	Bowl No.5
Lissapol- N detergent (gm/lit)	NIL	0.3	0.2	NIL	NIL
Sodium Carbonate(gm/lit)	0.5	NIL	NIL	NIL	NIL
Temperature (^{o}C)	45	45	45	40	40
Time (min)	3	3	3	1.5	1.5
Ultrasound	No	Yes	Yes	No	No

Table 2.2 Ultrasonic Scouring Recipe Without any chemical (i.e. without detergent and sodium carbonate)

Parameter	Bowl No.1	Bowl No.2	Bowl No.3	Bowl No.4	Bowl No.5
Lissapol- N detergent (gm/lit)	NIL	NIL	NIL	NIL	NIL
Sodium Carbonate(gm/lit)	NIL	NIL	NIL	NIL	NIL
Temperature (^{o}C)	60	55	50	40	40
Time (min)	3	3	3	1.5	1.5
Ultrasound	Yes	Yes	Yes	Yes	No

3.3 Process variables

To explore the possibility of reducing the process variables (time, temperature, chemical concentration, etc) following scouring trials were taken with and without ultrasound;

Table 3. Scouring Recipe for Reduction in Chemical Concentration

Parameter	Bowl No.1	Bowl No.2	Bowl No.3	Bowl No.4	Bowl No.5
Lissapol- N detergent (gm/lit)	NIL	0.6	0.4	NIL	NIL
Sodium Carbonate(gm/lit)	1.0	NIL	NIL	NIL	NIL
Temperature (°C)	60	55	50	40	40
Time (min)	3	3	3	1.5	1.5

Table 4. Scouring Recipe for Reduction in Scouring Temperature

Parameter	Bowl No.1	Bowl No.2	Bowl No.3	Bowl No.4	Bowl No.5
Lissapol- N detergent (gm/lit)	NIL	0.8	0.4	NIL	NIL
Sodium Carbonate(gm/lit)	1.33	NIL	NIL	NIL	NIL
Temperature (°C)	50	50	50	40	40
Time (min)	3	3	3	1.5	1.5

Table 5. Scouring Recipe for Reduction in Scouring Time

Parameter	Bowl No.1	Bowl No.2	Bowl No.3	Bowl No.4	Bowl No.5
Lissapol- N detergent (gm/lit)	NIL	0.8	0.4	NIL	NIL
Sodium Carbonate(gm/lit)	1.33	NIL	NIL	NIL	NIL
Temperature (°C)	60	55	50	40	40
Time (min)	2	2	2	1.0	1.0

Table 6. Scouring Recipe for Reduction in Chemical Concentration, Scouring Temperature as well as Scouring Time

Parameter	Bowl No.1	Bowl No.2	Bowl No.3	Bowl No.4	Bowl No.5
Lissapol- N detergent (gm/lit)	NIL	0.6	0.4	NIL	NIL
Sodium Carbonate(gm/lit)	1.0	NIL	NIL	NIL	NIL
Temperature (ºC)	50	50	50	40	40
Time (min)	2	2	2	1.0	1.0

4. Results and Discussion

The grease content of wool was tested by IWTO -10-02 Test Method for the determination of the dichloromethane soluble matter in scoured wool.

4.1 Results

4.1.1 Result for 20 micron wool

The results of residual grease content for 20 micron wool are as follows;

i. Grease content in raw wool : 15 %
ii. Conventional Aqueous Scouring Recipe (Table 1) : 0.65 %
iii. Ultrasonic scouring recipe (Table 2) : 0.37 %
iv. Conventional Aqueous Scouring Recipe with chemical concentration reduced to half and scouring temperature reduced to 45ºC (Table 1.1) : 4.62 %
v. Ultrasonic Scouring Recipe with chemical concentration reduced to half and scouring temperature reduced to 45ºC (Table 2.1) : 2.38%
vi. Conventional Aqueous Scouring Recipe Without any chemical (i.e. without detergent and sodium carbonate) (Table 1.2) : 7.22 %
vii. Ultrasonic Scouring Recipe Without any chemical (i.e. without detergent and sodium carbonate) (Table 2.2) : 3.88 %

Table 7. Results for 20 micron wool

S. no.	Description of the Scouring Recipe (Table no.)	Residual Grease Content (%)	
		Without ultrasound	With ultrasound
01	Scouring Recipe for Reduction in Chemical Concentration (Table 3)	0.86	0.45
02	Scouring Recipe for Reduction in Scouring Temperature (Table 4)	0.77	0.38
03	Scouring Recipe for Reduction in Scouring Time (Table 5)	0.72	0.48
04	Scouring Recipe for Reduction in Chemical Concentration, Scouring Temperature as well as Scouring Time (Table 6)	0.96	0.55

Figure 1: Effect of various scouring recipes on residual grease content of 20 micron wool

4.1.1.1 Scanning electron microscopy (SEM)

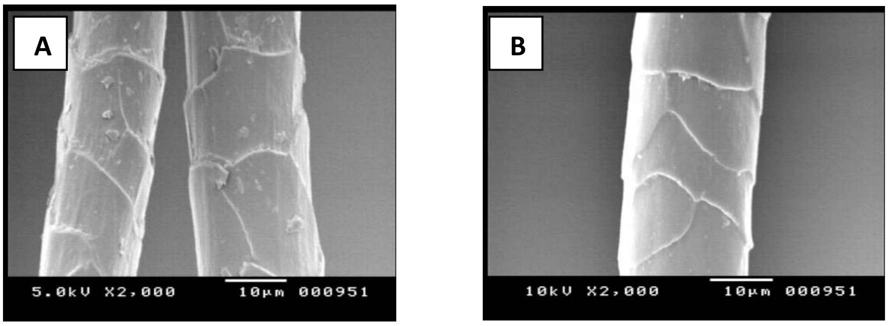

Figure: 2 SEM image of (A) Wool fibres scoured by conventional method-Table (B) Wool fibre scoured by ultrasound assisted method-Table2.

Wool fibres of 20 micron were taken from the samples scoured as per the scouring recipe described in Table1 and Table2 which were subjected to the most severe conditions. These wool fibre samples were coated with gold using JEOL JEC-550 twin coater before scanning electron microscopy. JEOL JSM-5400 scanning electron microscope was used for studying the surface morphology of conventionally scoured and ultrasonically scoured wool fibres.

From the SEM images, it is clear that ultrasound assisted scouring does not create any surface topographical changes and causes no damage to the wool fibres. The small flakes over the fibres in **image A** are not seen in ultrasonically scoured fibres in **image B**. The flakes or contaminants adhered to the fibre surface are wiped out by the micro-brushing action of ultrasonic irradiation.

4.1.2 Results for 24.5 micron wool

The results of residual grease content for 24.5 micron wool are as follows;

i. Grease content in raw wool : 12.8 %
ii. Conventional Aqueous Scouring Recipe (Table 1) : 0.58 %
iii. Ultrasonic scouring recipe (Table 2) : 0.32 %
iv. Conventional Aqueous Scouring Recipe with chemical concentration reduced to half and scouring temperature reduced to 45^{o}C (Table 1.1) :4.11 %
v. Ultrasonic Scouring Recipe with chemical concentration reduced to half and scouring temperature reduced to 45^{o}C (Table 2.1) :2.01 %
vi. Conventional Aqueous Scouring Recipe Without any chemical (i.e. without detergent and sodium carbonate) (Table 1.2) :6.72 %

vii. Ultrasonic Scouring Recipe Without any chemical (i.e. without detergent and sodium carbonate) (Table 2.2) :3.54 %

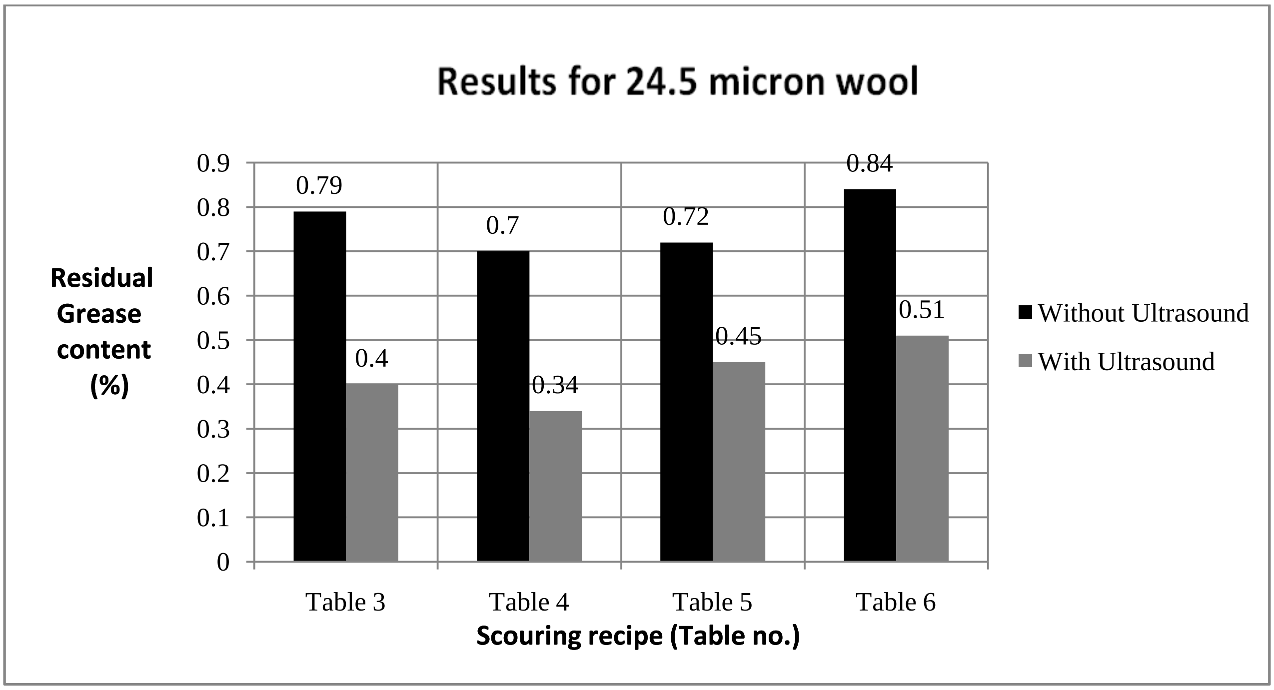

Figure 3: Effect of various scouring recipes on residual grease content of 24.5 wool

Table 8. Results for 24.5 micron wool

Sr.no.	Description of the Scouring Recipe (Table no.)	Residual Grease Content (%)	
		Without ultrasound	With ultrasound
01	Scouring Recipe for Reduction in Chemical Concentration (Table 3)	0.79	0.40
02	Scouring Recipe for Reduction in Scouring Temperature (Table 4)	0.70	0.34
03	Scouring Recipe for Reduction in Scouring Time (Table 5)	0.72	0.45
04	Scouring Recipe for Reduction in Chemical Concentration, Scouring Temperature as well as Scouring Time (Table 6)	0.84	0.51

4.1.3 Results for 30 micron wool

The results of residual grease content for 30 micron wool are as follows;

i. Grease content in raw wool :11 %
ii. Conventional Aqueous Scouring Recipe (Table 1) :0.51 %
iii. Ultrasonic scouring recipe (Table 2) :0.26 %
iv. Conventional Aqueous Scouring Recipe with chemical concentration reduced to half and scouring temperature reduced to 45^{o}C (Table 1.1) :3.38 %
v. Ultrasonic Scouring Recipe with chemical concentration reduced to half and scouring temperature reduced to 45^{o}C (Table 2.1) :1.77 %
vi. Conventional Aqueous Scouring Recipe Without any chemical (i.e. without detergent and sodium carbonate) (Table 1.2) :5.97 %
vii. Ultrasonic Scouring Recipe Without any chemical (i.e. without detergent and sodium carbonate) (Table 2.2) :3.04 %

Table 9. Results for 30 micron wool

Sr.no.	Description of the Scouring Recipe (Table no.)	Residual Grease Content (%)	
		Without ultrasound	With ultrasound
01	Scouring Recipe for Reduction in Chemical Concentration (Table 3)	0.70	0.36
02	Scouring Recipe for Reduction in Scouring Temperature (Table 4)	0.62	0.30
03	Scouring Recipe for Reduction in Scouring Time (Table 5)	0.64	0.35
04	Scouring Recipe for Reduction in Chemical Concentration, Scouring Temperature as well as Scouring Time (Table 6)	0.76	0.39

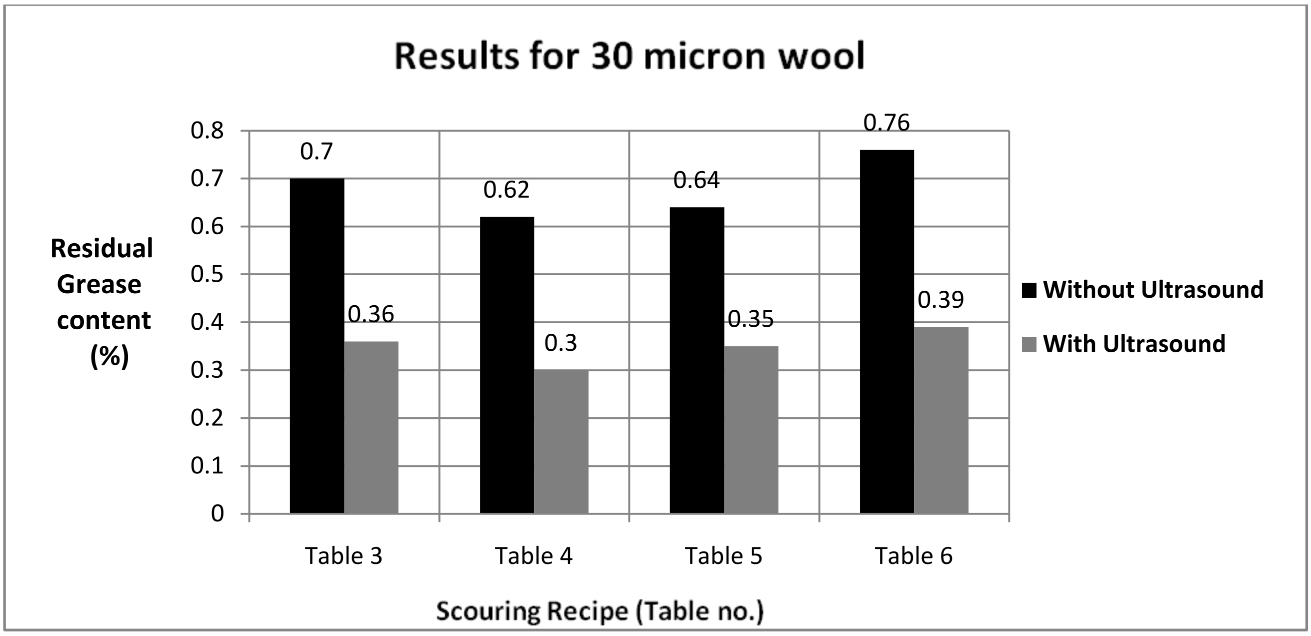

Figure 4: Effect of various scouring recipes on residual grease content of 30 micron wool

Up-scaling of Lab model of ultrasonic scouring

i) The lab model was a specially designed vessel with a capacity of 28 litres lined with extra transducers on the side walls so as to produce ultrasonic irradiation from all sides to the sample subjected to scouring.

ii) At industry level the process of scouring is continuous through 3 to 6 bowls which requires an attachment type of transducers either temporarily or permanently fixed inside the bowl.

iii) Two tube resonators of 25 KHz frequency, 476 mm and 572 mm in length producing 1kW of output power were immersed into the 2^{nd} and 3^{rd} scouring bowl of an industrial scale scouring machine.

Table 10. Up-scaling of lab model to industrial level

Process Description	Residual grease content
Conventional Scouring	0.49 %
Ultrasonic scouring with tube resonators	0.27 %

From the bulk trials of the greasy wool with ultrasonic tube resonators suspended into the liquor bath, the results obtained in scouring efficiency are in tune with those attained during the lab model trials (Table 10).

4.2 Discussion

From above results it is clear that ultrasound can be used to scour the wool fibres with substantial savings in scouring temperature, time, concentration of alkali and detergent. It is also evident that scouring of coarser wool is much easier than medium or finer varieties which may be due to lesser initial grease content in their raw form. It may also be due to the fact that the total surface area to be cleaned in case of coarser wool fibres is much lesser as compared to finer fibres. The scouring of wool in presence of ultrasonic irradiation helped to scour the fibres more efficiently without any visible entanglement of fibres. This can be explained as follows; The ultrasonic energy created compression and rarefaction waves in the liquid medium. During the rarefaction phase of the wave, the liquid molecules are stretched apart, creating an area of low density. This gives rise to formation of millions of microscopic bubbles (cavitations) which implode as the compression (high density) wave reaches towards them. These implosions liberate vast amount of energy in the form of micro-jets (micro streaming) of liquid. When these micro-jets collide with the wool fibre surface, they take away even the tightly bound impurities from the fibres. This mechanical energy of imploding cavities creates a micro-brushing sort of an action and accelerates the cleaning action of chemicals like detergent and alkali. Thus, ultrasound accelerates the scouring process.

5. Conclusion

Wool scouring has remained more or less untouched by the latest developments in the field of textile research, in spite of being the first and a very crucial stage in the wool processing. From the present study, the possibility of using ultrasonic irradiation in the wool scouring process has been assessed. It was found that coarser fibres can be very easily scoured with the help of ultrasound as compared to finer fibres. The study suggests that the grease and suint removal efficiency of conventional scouring process can be almost doubled with the introduction of ultrasonic irradiation in the second and third scouring bowls. The study revealed the efficacy of using ultrasound in the scouring process to accelerate the process of removal of contaminants from the raw wool and suggests ultrasound assisted scouring can be done at much lower temperature (50^{o}C), utilizing lesser amount of chemicals (1 gpl of both alkali and detergent) and with substantial saving in time. Furthermore, the bulk trials revealed that the ultrasonic technique can be readily up-scaled to the industrial level with the help of immersible type of tube resonators.

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